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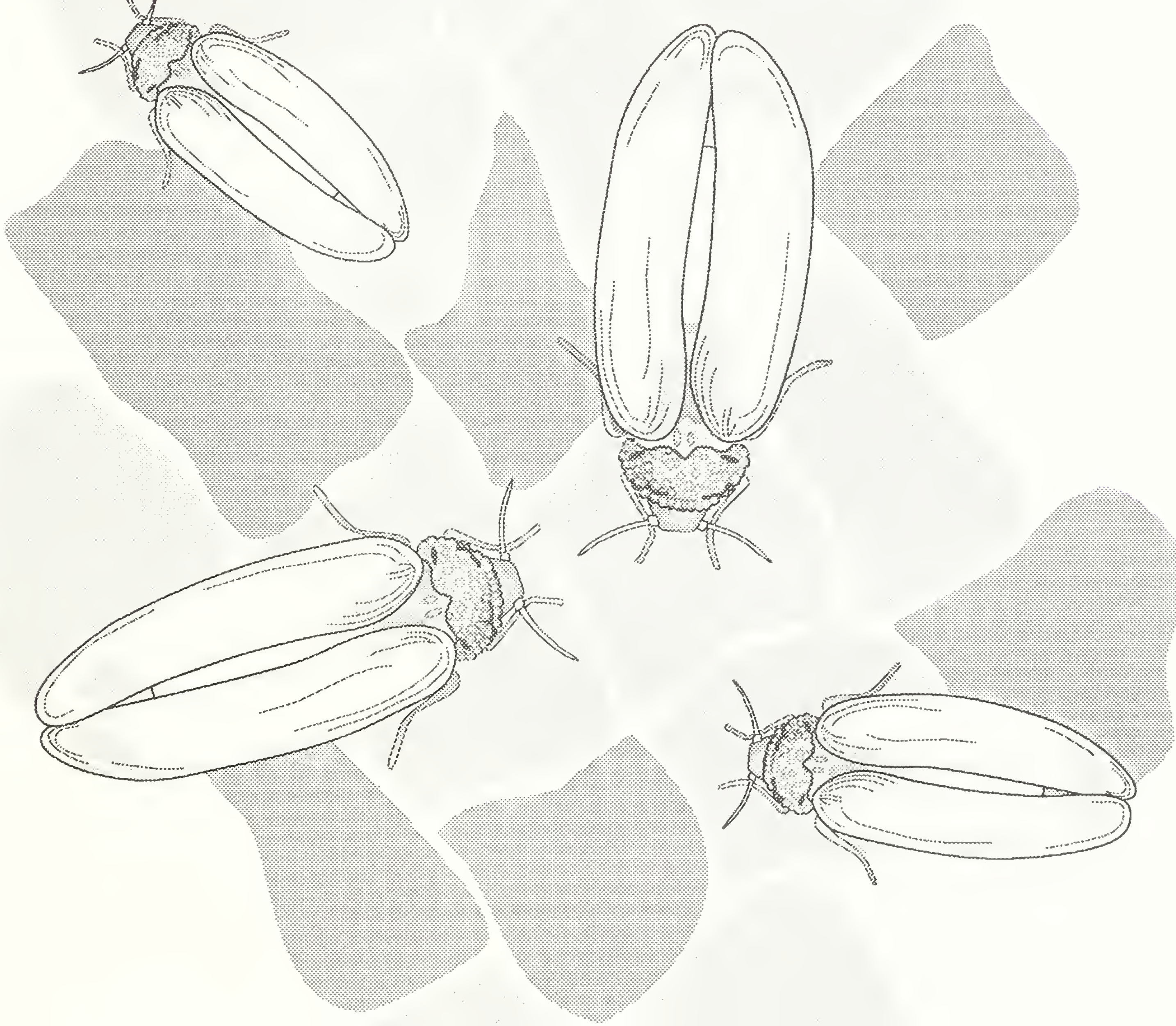
Conference Report and 5-Year National Research and Action Plan for Development of Management and Control Methodology for the Sweetpotato Whitefly

Houston, Texas
February 18-21, 1992

In cooperation with—
USDA Cooperative State Research Service and the
State Agricultural Experiment Stations
USDA Animal and Plant Health Inspection Service
USDA Extension Service



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United States Department of Agriculture

Agricultural Research Service

National Program Staff

Beltsville, Maryland 20705

July 13, 1992

SUBJECT: Conference Report and 5-Year National Research and Action Plan for Development of Management and Control Methodology for the Sweetpotato Whitefly

TO: Conference Participants and Other Interested Parties

FROM: Robert M. Faust
National Program Leader
Fundamental & Molecular Entomology - Plants

James R. Coppedge
National Program Leader
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Attached herewith is the Conference Report and 5-Year National Research and Action Plan for Development of Management and Control Methodology for the Sweetpotato Whitefly resulting from the working conference held in Houston, Texas, February 18-21, 1992. It is important that we all continue to recognize the vital relationships between the Agricultural Research Service, the Cooperative State Research Service, APHIS, the State Agricultural Experiment Stations, State Departments of Agriculture, the Extension Service, commodity and industry groups, and others having a vested interest in this serious pest. This action plan provides an important foundation for program strengthening and expansion, coordination, decision making and implementation, and ultimate technology transfer to users.

On behalf of the ARS National Program Staff, we would like to take this opportunity to again express our appreciation and thanks to each of you for your input and participation in the planning conference. The conference resulted in very fruitful discussions and research recommendations. We look forward to continuing the development of close cooperative relationships and a research and action program that is responsive to the needs and priorities of the agroindustry and other stakeholders. We also look forward to meeting with you again in the future as we move ahead in this program, and we trust that your participation in this important activity was as informative and pleasant as it was to us.

Lastly, as was discussed during the conference, the plan being put in place will be a dynamic one. Progress in reaching the goals of the plan will be reviewed on an annual basis. All participants are encouraged to continue giving thought to the specifics of work plans for FY 93 as they move forward with the efforts being undertaken for FY 92. Again, our aim is to provide the research and technology to support the implementation of State and Federal action and regulatory programs and technology transfer to users.

TABLE OF CONTENTS

PREFACE

This conference report and 5-year National Research and Action Plan for Development of Management and Control Methodology for the Sweetpotato Whitefly (SPW) details a cooperative and cohesive team effort to help solve a serious national pest problem. This has required a detailed formulation of a comprehensive action program that clearly defines and states program goals and objectives, identifies each project relevance and role, identifies activities to reach the objectives, establishes time frames needed to reach objectives, and provides a basis for participation of all groups in planning the program. This comprehensive plan should provide (a) focus and programmatic stability, (b) a basis for monitoring and evaluating program progress, (c) a basis for developing budget estimates and allocating resources, (d) responsiveness to the technology and problem-solving opportunities, and (d) development of team players and teamwork.

The primary aim of the 5-Year National Research and Action Plan is to provide the necessary research and team effort that will continue to yield environmentally and publicly acceptable, safe technologies for area-wide management and suppression of the SPW. The plan is designed to be dynamic and responsive to needs and priorities. Progress in reaching goals will be reviewed on an annual basis. As the program progresses, participants will play a significant role in redefining essential activities in eliminating some proposed activities that may result from the inherent uncertainties of research, and in assigning appropriate remaining activities or selecting new activities to achieve goals.

We express gratitude and appreciation to all working conference attendees for participating in the organization and proceedings of the conference and in formulating this comprehensive national action plan. The Interagency SPW Working Group members are especially indebted to the representatives from industry, commodity groups, and Federal and State institutions for their valuable interactions and contributions. Special appreciation is accorded to Dr. Jose Amador and his staff, Texas A&M University, and to Drs. Raymond Carruthers and Thomas Henneberry and their staffs, ARS for the considerable time and effort that they devoted from the inception of this important activity. We would like to also personally express our appreciation to the members of the SPW and ad hoc Working Group and to the Steering Committee for all the energy they brought to bear in order to make this conference a high success. We also would like to acknowledge the specific universities who contributed to the conference and action plan, and who are integral partners in this effort: University of Arizona, University of Arkansas, University of California, Clemson University, Cornell University, University of Florida, University of Georgia, University of Hawaii, Mississippi State University, New Mexico State University, Ohio State University, and Texas A&M University.

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I. Executive Summary

A major responsibility of the agricultural research community is the discovery and development of environmentally compatible and publicly-acceptable pest control strategies. Many major insect pests are resistant to a number of current control methods that rely upon synthetic chemical pesticides. Integrated management strategies seem to offer the best promise for control of these pests.

The sweetpotato whitefly (SPW), *Bemisia tabaci* Gennadius, also known as the cotton, "poinsettia," cassava and tobacco whitefly, is a serious pest of cultivated crops in South and Central America, the West Indies, Africa, Asia, and southern Europe. The SPW was recorded in Florida from sweetpotato plants as early as 1894. It was collected in Texas from weeds in 1946, on cotton in Texas in 1959, and on sweetpotatoes in Georgia in 1950. Large populations in Florida were not reported until massive outbreaks occurred in greenhouse poinsettia crops in 1986. In 1987-88, outbreaks were widely reported in Florida field tomato crops as well. SPW is now a major pest of tomato, cole crops, cucurbits, and many different ornamentals in many parts of the United States, in addition to Florida. The subtropical climate allows year-round populations of whitefly to persist on over 130 species of plants in Florida; including native plants, weeds, landscape ornamentals, bedding plants, and vegetables. It has also been reported from citrus, peanuts and sesame. The SPW has become of increasing importance since the early 80's in cotton production systems in Arizona and California, as well as in cultivated vegetable crops. SPW studies from 1962 to 1965 in southern California cotton indicated that SPW did not usually cause economic damage. But, when economic populations did occur, they usually developed following insecticide application, suggesting that natural control factors played an important role in regulating whitefly populations. The SPW has also become an important pest in the northeast U.S. where it is found infesting greenhouse grown ornamentals in several states. In New Jersey, it is estimated that crops in 80% of the commercial greenhouses were infested by this pest with costs for control and damage again ranging in the millions of dollars. The widespread shipment of ornamentals threatens to distribute these populations around the country. With these outbreaks and more recent problems in numerous crops in Texas, Arizona, and California, it has become apparent that the whiteflies now causing these problems exhibited biological differences from the original southwestern U.S. population. The epidemic outbreaks of the SPW in Arizona and California beginning in the early 1980's, as well as those in Texas in 1988 and in Florida in 1987 remain unexplained; although it has been suggested that the recent outbreaks, different host preferences, and other biological differences are consistent with the introduction of an exotic SPW population, possibly even a closely related but different species. Economic losses in cotton, ornamental, and vegetable crops can result from direct feeding damage and reduced yield, lint contamination with honeydew, and associated fungi. The SPW is also a vector of cotton leaf crumple, cotton leaf curl, and infectious yellows and squash leaf curl affecting a wide range of cultivated vegetable crops. Dollar losses have exceeded $200 million annually nationwide. In

addition, there are new diseases such as irregular ripening in tomatoes, and squash silverleaf that were first reported in Florida, but are now observed elsewhere. In the Florida tomato industry alone, it is estimated that this pest caused losses of $30 million in 1988. In the Rio Grande Valley of Texas, the SPW is now heavily infesting over 100,000 acres of cotton and in 1991 was estimated to cause losses of roughly $80 million. Coupled with losses caused in fruit and vegetable production, the 1991 losses to the Rio Grande Valley are now estimated to exceed $100 million (Rio Grande Valley SPW Task Force). Similar losses have been reported from other cotton and vegetable production regions throughout the area of SPW infestation.

A cooperative effort involving USDA agencies (ARS, APHIS, CSRS, and CES), state agricultural experiment stations, and cotton, vegetable, ornamental and nursery crop industry representatives is being undertaken to formulate cooperative programs, address priority research areas, avoid duplication of effort and maximize use of existing resources. An Interagency Workshop for the Development of Management and Control Methodologies for the Sweetpotato Whitefly was held on February 18-21, 1992, in Houston, TX. The purpose of the working conference was to: (1) develop and implement a 5-Year National Research and Action Plan for Management and Control of the Sweetpotato Whitefly; (2) foster communication, linkages, and coordination among scientists and others having an interest in sweetpotato whitefly management and control; (3) discuss the current status, research activities, and constraints in using available knowledge and technology for managing the sweetpotato whitefly; (4) clarify research needs, opportunities, and strategies for integrating interdisciplinary, interagency, and industry resources for managing sweetpotato whitefly; and (5) validate roles and responsibilities in implementing identified research needs and opportunities.

High priority areas for coordinated research and development are included in the 5-year national action plan: (1) Ecology, Population Dynamics, and Dispersal; (2) Fundamental Research - Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions; (3) Chemical Control, Biorationals, and Pesticide Application Technology; (4) Biological Control; (5) Crop Management Systems and Host Plant Resistance; and (6) Integrated Techniques, Approaches, and Philosophies.

This report and national action plan provides an important foundation for coordinated program strengthening and expansion, decision making, and implementation actions, and is a detailed plan of work (inclusive of all cooperating agencies and institutions) and is an umbrella document to be used by all groups to guide their research and action efforts. Workshops will be held each fall to review progress and to adjust the plan as needed.

II. Objectives and Charge to the Workshop

The overall charge to the working conference was to develop and implement a 5-year national research and action plan for management and control of the sweetpotato whitefly, *Bemisia tabaci*. The workshop was specifically designed to provide a forum for expressing views, generating ideas, and identifying gaps, needs, and areas of cooperation leading to technologies for sweetpotato whitefly (SPW) management and control.

Specific Objectives were to:

1. Foster communication, linkages, and coordination among scientists and others having an interest in sweetpotato whitefly management and control.

2. Discuss the current status, research activities, and constraints in using available knowledge and technology for managing the sweetpotato whitefly.

3. Clarify research needs, opportunities, and strategies for integrating interdisciplinary, interagency, and industry resources for managing sweetpotato whitefly.

4. Validate roles and responsibilities in implementing identified research needs and opportunities.

On October 24-25, 1991, a Sweetpotato Whitefly Ad Hoc Working Group meeting was held in Atlanta, Georgia, to initiate planning for a coordinated effort in SPW research. Twenty-six scientists, representing ARS, APHIS, State Experiment Stations and various commodity groups participated. Based on the group discussions, five action areas were identified as of the highest priority for development into a coordinated national plan: (a) Ecology/Population Dynamics; (b) Fundamental Biology/Virology; (c) Integrated Crop Management; (d) Chemical Control; and (e) Biological Control. R. I. Carruthers and T. J. Henneberry were selected as co-organizers to develop an agenda and to organize a comprehensive working conference,; subject area coordinators were identified from various agencies and institutions to aid in the development of a draft written action plan and to help plan the conference. Subsequently, a combined group of forty individuals representing several state universities, USDA-CSRS, USDA-APHIS, USDA-ARS, USDA-CES, and commodity groups, met in Reno, NV on December 12-13, 1991, to further coordinate the activities at the national level as supported by the Secretary of Agriculture's Office. The group supported the concept of a highly coordinated, cooperative research and action plan, discussed methods to develop the comprehensive 5-year plan of work, highlighted priority areas for immediate action from the draft 5-year plan that had been prepared, discussed on-going efforts in the priority areas, and identified gaps not currently being covered.

This working conference represents the culmination of the two earlier meetings; the action plan contained herein represents a detailed plan of work (inclusive of all cooperative agencies and institutions), and is an umbrella document to be used by all groups to guide their research and action efforts. Workshops will be held each fall to review progress and to adjust the plan as needed.

A 5-Year National Research and Action Plan for Development of Management and Control Methodology for Sweetpotato Whitefly, *Bemisia tabaci* (Gennadius)

III. Introduction - Statement of the Problem

The sweetpotato whitefly (SPW), *Bemisia tabaci* Gennadius, also known as the cotton, "poinsettia", cassava and tobacco whitefly, was first described as *Aleyrodes tabaci* from tobacco in Greece in 1889. SPW is a serious pest of cultivated crops in South and Central America, the West Indies, Africa, Asia, and southern Europe. The SPW was recorded in Florida from sweetpotato plants as early as 1894. It was collected in Texas from weeds in 1946, on cotton in Texas in 1959, and on sweetpotatoes in Georgia in 1950. Large populations in Florida were not reported until massive outbreaks occurred in greenhouse poinsettia crops in 1986. In 1987-88, outbreaks were widely reported in Florida field tomato crops as well. SPW is now a major pest of tomato, cole crops, cucurbits, and many different ornamentals in many parts of the United States in addition to Florida. The subtropical climate allows year-round populations of whitefly to persist on over 130 species of plants in Florida; including native plants, weeds, landscape ornamentals, bedding plants, and vegetables. It has also been reported from citrus, peanuts and sesame.

The SPW has become of increasing importance since the early 80's in cotton production systems in Arizona and California, as well as in cultivated vegetable crops. The first SPW were collected from cotton in the United States at Gila Bend, AZ in 1926, followed by collections at Calipatria, CA in 1928, and a number of other California locations from cotton during the years 1950 to 1954. SPW studies from 1962 to 1965 in southern California cotton indicated that SPW did not usually cause economic damage. But, when economic populations did occur, they usually developed following insecticide application, suggesting that natural control factors played an important role in regulating whitefly populations.

The SPW has also become an important pest in the northeast U.S. where it is found infesting greenhouse grown ornamentals in several states. In New Jersey, it is estimated that crops in 80% of the commercial greenhouses were infested by this pest with costs for control and damage again ranging in the millions of dollars. The greatest use of pesticides (on basis of lbs/unit area and frequency) occurs in the greenhouse industry. This results in the greatest pressure for development of resistance of any industry. Many pesticides are registered first on ornamentals, and significant tolerance by *Bemisia* has developed to some chemicals before they are available for use on other crops. The widespread shipment of ornamentals threatens to distribute these populations around the country.

With these outbreaks and more recent problems in numerous crops in Texas, Arizona, and California, it became apparent that the whiteflies now causing these problems exhibited biological differences from the original southwestern U.S. population. The epidemic outbreaks of the SPW in Arizona and California beginning in the early 1980's, as well as those in Texas in 1988 and in Florida in 1987 remain unexplained, but a number of contributing factors have been suggested. Increasing populations in 1981 were followed by several warm winters. Under mild winter conditions, the SPW could have invaded and adapted to more northerly habitats than its normal world-wide distribution around the 30th parallel. Additionally, increased survival of many frost-susceptible weeds may have occurred, greatly expanding SPW overwintering host sites. Also, increasing SPW populations occurred coincidentally with the increasing use of pyrethroid insecticides in the late 70's. Other possibilities include high overwintering survival on "stub" cotton that was an accepted cotton culture in Arizona between 1978 and 1982, and the development of insecticide resistance. Similar explanations have been reported for the increasing SPW problem throughout the world and other areas in the United States. It has also been suggested that the recent outbreaks, different host preferences, and other biological differences are consistent with the introduction of an exotic SPW population, possibly even a closely related but different species.

The considerable circumstantial and factual evidence available suggests that some combination or all of these factors may have contributed to the complexity of the SPW problem. The biological adaptability of the SPW is very evident from its long list of host plants and occurrence of biotypes or populations with different biological characteristics. Observations of SPW outbreaks in the United States and in other parts of the world by whitefly researchers have prompted renewed interest in the phenomenon of biotypes or strains. Research has been initiated to characterize the differences between whitefly populations and to allow definitive identifications of whiteflies from these groups. Because of the variability in biological attributes among SPW populations, it is necessary to interpret with caution earlier literature on SPW, realizing that populations discussed in these studies may have different attributes from those in other areas. Until the nature and origin of this pest has been definitively determined, further discussion of SPW should clearly specify the populations in question. Based upon characteristic biochemical markers, populations associated with poinsettia and cole crops have been designated as the "B" biotype, while the historically indigenous, cotton-derived population is termed the "A" biotype. Many of the populations now attacking a wide variety of crops across the southern U.S. appear to consist of biotype "B". In the absence of definitive identifications, the year of infestation, geographic location, and host plants affected should be specified.

Economic losses in cotton, ornamental, and vegetable crops can result from direct feeding damage and reduced yield, lint contamination with honeydew, and associated fungi. The SPW is also a vector of cotton leaf crumple, cotton leaf curl, and infectious yellows and squash leaf curl affecting a wide range of cultivated vegetable crops. Dollar losses have exceeded $200 million annually nationwide. In addition, there are new diseases such as

irregular ripening in tomatoes, and squash silverleaf that were first reported in Florida, but are now observed elsewhere. In the Florida tomato industry alone, it is estimated that this pest caused losses of $30 million in 1988. In the Rio Grande Valley of Texas, the SPW is now heavily infesting over 100,000 acres of cotton and in 1991 was estimated to cause losses of roughly $80 million. Coupled with losses caused in fruit and vegetable production, the 1991 losses to the Rio Grande Valley are now estimated to exceed $100 million (Rio Grande Valley SPW Task Force). Similar losses have been reported from other cotton and vegetable production regions throughout the area of SPW infestation.

A cooperative effort involving USDA agencies (ARS, APHIS, CSRS, AND CES), state agricultural experiment stations, and cotton, vegetable, ornamental and nursery crop industry representatives is being undertaken to formulate cooperative programs, identify priority research areas, avoid duplication of effort and maximize use of existing resources. The cooperative effort will also identify high priority areas of additional needed research.

IV. Research and Implementation Areas

A. Ecology, Population Dynamics, and Dispersal

1. Introduction

The development of effective and efficient integrated pest management programs for SPW requires a basic understanding of their biology and ecology and of the factors influencing the temporal and spatial components of their population dynamics. Currently, pesticides represent the primary tool for controlling SPW populations. In the Southwestern U. S. it is not uncommon for growers to make biweekly applications to cotton and vegetable fields throughout the late summer/early fall seasons at costs in excess of $350 per acre for the three month period from August through October. Similar scenarios are common in other areas, such as Florida where pesticide applications are made from late summer through early spring, and Hawaii where pesticides are applied 10 months of the year. The severity of the situation mandates the need for alternative control strategies that can only be developed after we thoroughly understand certain components of the basic biology of this insect. Population dynamics and dispersal are clearly two areas that need to be examined more carefully.

The SPW has been reported from 500 host plants worldwide and the list continues to grow in the United States and elsewhere. This diversity of cultivated and weed hosts increases the complexity of the problem by increasing host biomass and providing a constant source of host material that can be exploited for reproduction and survival via intercrop movement over space and time. The typical annual sequence of cultivated field and greenhouse crops grown in the Southwest, the Rio Grande Valley, Texas, Florida, and Hawaii affords the SPW a source of food, shelter and reproductive substrate throughout the year. The importance of this intercrop movement within the agricultural community cannot be overstated as a factor in developing control strategies.

A systematic and coordinated research effort is needed to address the factors that drive both the temporal and spatial components of the population dynamics of SPW. A fundamental requisite for both research and decision-making purposes is the development of efficient and precise sampling protocols for adult and immature stages applicable to each of hosts inhabited by SPW. Scientists need to more thoroughly define the wild and crop hosts species important to SPW dynamics throughout the season and understand the contribution of these hosts to population growth and virus transmission. The role of intra- and inter-host dispersal on population redistribution through both time and space needs to be more clearly defined. An understanding of the basic biological and ecological factors influencing dispersive and migratory behaviors is essential to these efforts. Finally, we need to integrate this knowledge into quantitative population

models that will enable us to predict SPW dynamics and, thus, better manage this insect within the agricultural community.

2. **Research Accomplishments**

Population Dynamics

Life History and Voltinism. Many researchers have reported on adult longevity, fertility, and preimaginal developmental and survival rates. Some generalizations can be made from such studies. Lower and upper developmental threshold temperatures appear to be near 10 and 32°C, respectively. Development on cotton from egg to adult occurs in less than 17 days at 30°C. A temperature of 27°C seems to be optimal. Developmental times vary with the season, but development from egg to adult takes from 25 to 50 days under field conditions. There is some degree of variation in reported vital rates and these are attributable in part to the use of different populations. Additionally, important differences in development, survival and fertility are caused by rearing on different host plants. Preimaginal survival varies inversely with relative humidity, with survival varying from 2-80% in the range of 31-90% relative humidity. Fertility varies from approximately 80 to more than 300 eggs per female. Additionally, it appears as though the host upon which SPW is reared plays an important role in fertility levels. Females live from 10-15 days at temperatures typical of summer conditions and may live several months during the winter. Finally, evidence suggests that at least two putative biotypes exist with different biological characteristics, including differences in vital rates, varying vector efficiencies, and differences in host range and honeydew production.

The SPW has a multivoltine life history. Between 16 and 17 generations per year were reported in West Bengal. This species develops and breeds continually so long as temperature conditions permit; the species is thought to have developed in a tropical or subtropical region. It is estimated that approximately 320 degree-days are necessary to complete one generation.

Population Growth and Overwintering. Studies of the population dynamics of SPW in natural settings are somewhat lacking. Most reports concern populations which are introduced into regions where they subsequently increase dramatically. In such settings, populations often appear to increase unchecked except by the limitation of suitable foliage and certain abiotic factors. Whitefly populations can reach enormous densities, causing leaf chlorosis, leaf withering, premature dehiscence, defoliation, and plant death. Nymphal densities of 20-100/cm^2 or up to several thousand per leaf are reported in such circumstances. Egg densities can be as high as 1,200/in^2. SPW populations have the potential for exponential growth under favorable conditions of climate and host-plant availability.

SPW infestations in cotton fields are initiated during May or earlier in the year when adults move from overwintering hosts and/or other cultivated hosts. Populations of immature SPW develop slowly through June and early July, expand rapidly in late July and August, reaching peak numbers in September, declining thereafter until the crop is harvested.

During the winter months in the Southwest SPW populations are generally at their lowest point. Immature stages, SPW adults, and parasites are found on *Malva parviflora* L., as well as *Helianthus annuus* L., *Convolvulus arvensis* L., and *Lactuca serriola* L. Cultivated crops grown in winter months in the southern U.S. which are hosts include tomato, *Lycopersicon esculentum* M., carrot (*Daucus carota* L.), broccoli (*Brassica oleracea* L.), squash (cucurbita spp.), eggplant (*Solanum melongena* L.), guar [*Cyamopsis tetragonoloba* (L.) Taub.], guayule (*Parthenium argentatus* A. Gray), alfalfa (*Medicago sativa* L.) and lettuce (*Lactuca sativa* L.), aș well as various cole and cucurbit crops. In south Florida the lowest SPW populations are commonly found during the summer months. In Hawaii populations of SPW may remain high most of the year due to the wide diversity of cultivated crops, many of them unique to the area.

Life Tables and Population Models. The only comprehensive life-table study conducted to date was done on cotton in Israel. This study demonstrated that the majority of mortality occurred during the crawler and first-instar nymphal stages and was primarily due to weather and predation. Later nymphal mortality was moderate, due mainly to weather and parasitism, and egg mortality was minimal.

Several models have been developed to describe the population dynamics of SPW in cotton. A simple degree-day model developed in California describes exponential SPW population growth based on observed generation times in cotton. The model is sensitive to initial population estimates and does not include factors such as host-plant effects or natural enemy mortality, however, it has found utility in projecting area-wide population trends based on historical weather data. A second, more comprehensive life-table model was developed in the Sudan. The model incorporates many of the salient processes influencing population growth including development, fecundity, survival and natural enemy impact. Also, because the insect model was linked with a physiologically-based cotton plant model it incorporates host-plant nutritional effects on insect life history. The model has been useful in studying the dynamics of SPW/cotton interactions.

Sampling. SPW populations are highly aggregated both within and between plants. Adult females oviposit preferentially on young foliage and crawlers do not move any significant distance from eclosion site, thus, immature stages tend to be distributed vertically on the plant with older stages found on progressively

older leaves. Seasonal patterns of plant growth and activity by natural enemies can influence this distributional pattern to varying degrees. Immature numbers per plant can be determined by direct enumeration; however, estimation of numbers becomes more difficult and time-consuming as plant size and insect densities increase. Sampling effort has been reduced by counting immatures or rating densities on smaller sections of entire leaves and by selecting leaves from specific nodes containing the highest densities of the desired stage. Several workers have related the nodal position of most infested leaves with plant development and correlated densities per plant with counts on these leaves. Utilizing mean-variance relationships, fixed-precision sequential sampling plans and presence-absence sampling plans have been developed for red-eye nymphs on cotton.

A greater number of techniques have been developed for estimating adult SPW densities. Among the techniques that have been examined are whole plant sampling or counts on individual leaves early in the morning, vacuum sampling, sticky traps, rating of adult SPW clouds from disturbed plants and beating plants above vegetable oil-coated pans. Yellow sticky traps have been the most widely used sampler for adults, and factors such as trap placement, exposure interval, trap configuration, and the influence of environmental factors such as wind and temperature have been examined. Cylindrical traps are the most effective as they function independent of wind direction or crop source and traps placed nearer the ground are more effective than those placed higher within or outside the crop canopy. There is some disagreement as to whether horizontally- or vertically-oriented traps are more effective. Duration of trapping intervals also influences effectiveness. Generally, shorter observation intervals (<24) result in greater catch. Trap catches during daylight hours are positively correlated with temperature. Attempts to correlate trap catches with actual population levels in the field have provided variable results. Due partly to increased immature mortality with increasing population density, correlations between field populations and trap catches become poorer as field population densities increase. Other factors such as the relative size and attractiveness of the trap in relation to the crop through the season also influence the correlation of trap catches with field population densities. This is an area of research that needs further attention if sticky traps are to provide reliable estimates for research and pest management applications.

Dispersal

The role of inter- and intra-crop movement of the SPW is not well understood, but some insight into the magnitude of the problem is becoming evident. Short-range movement within and between cultivated and weed host plants is known to take place regularly. There is also evidence of long-range whitefly migration similar to that described for other homopterans. Long-range

movement of SPW adults has been reported after collections in aircraft-mounted nets at high altitudes. Moreover, the density of airborne insects may increase several fold as a result of the concentrating effect of vertical convection currents and horizontal air movement associated with weather fronts causing densities to reach economic levels during redistribution. SPW have been captured at distances of up to 12 km from their point of origin. The range of effective migration, or migration that results in colonization of the new habitat, by SPW has not been satisfactorily established.

In the Southwest dispersal occurs primarily in the spring when populations of SPW are leaving overwintering hosts such as cheeseweed, *M. parviflora*, and groundcherry, *Physalis wrightii* Gray, and in the late summer/early fall when populations are experiencing the exponential and asymptotic phases of their growth curve and are moving from cotton and melons to vegetables and alfalfa. Problems associated with whiteflies and viral pathogens are often linked to these massive migrations in the fall. For example, SPW dispersal from heavily infested cotton and melon fields 1.4 to 4.8 km from lettuce fields in Arizona resulted in a daily rate of increase of adults in lettuce of $b = 0.14$, showing the extreme population pressure that may occur as a result of migrating SPW. Also, up to 50% of the SPW collected were capable of vectoring lettuce infectious yellows virus. In the Southeast crop hosts are maintained during the fall, winter and spring months so that a great deal of dispersal takes place during those seasons. In contrast to the Southwest, crop hosts are not available during the summer months.

Although relatively long-range movement occurs, shorter-range migration predominates once SPW are established in an area which has crop and weed hosts available all year. In the Middle East and India SPW populations overwinter on a variety of cultivated and wild vegetation such as cheeseweed and vegetables and then move to spring hosts such as potato and cultivated sunflower. In every situation where whiteflies are a serious problem, these wild and cultivated hosts grow in close proximity to one another. Apparently much of the short-range movement occurs near ground level (below 10 cm) and flight occurs primarily during the morning and midday hours and flight activity is unimodal.

It is suggested that subsets of whitefly populations leave their original habitat in response to deteriorating conditions in search of better feeding or oviposition sites. Having left the original habitat, they have little control over what happens. Adult whiteflies were routinely observed in the upper part of a cotton crop canopy, while the majority of whiteflies migrating between habitats moved quickly to the ground after leaving the field. The direction of their flight is primarily dictated by the wind. They land on particular plants mostly by chance, electing to stay on suitable hosts and move away from those that are not.

The influence of various environmental and biological factors on dispersive behavior is currently being examined. Freeflight behavior of SPW in a vertical flight chamber indicated that although flight propensity is comparable for 0600-1900 h, flight duration is maximum from 0600-1000 h under a 13L:11D photo-regime. Males fly longer than do females (14.5 vs. 9.14 min) and fly consistently throughout the day, whereas females fly longer from 0600-1200 h than from 1300-1900 h. Both sexes are capable of sustaining flight for more than 2 h, although less than 5% of the individuals examined fly this long.

Flight activity also is influenced by age and by host quality. The propensity to takeoff, the proportion exhibiting phototactic orientation, and flight duration are affected by age. Host quality does not significantly affect propensity to takeoff or flight duration, but does affect phototactic orientation. Whiteflies reared on leaves in an advanced state of senescence are more likely to exhibit phototactic orientation. Host quality also significantly affects whitefly mass. Both sexes are smaller when reared on senescing compared with vegetative tissue.

In individual SPW that exhibited a phototactic response, flight was characterized initially by a strong phototactic and photokinetic response. Over the course of the flight these responses declined and flight instability increased. Although males and females displayed similar flight characteristics, females exhibited higher rates of climb than did males (3.08 vs. 2.31 cm/s). For both males and females, individuals that flew longer than 25 min had a higher rate of climb than did individuals that flew for less than 25 min. This is evidence that SPW is capable of long range migration, but range has not been substantiated in field studies.

Whiteflies have relatively low wing loading values (0.00174-0.00532 g/cm^{-2}) and relatively high wingbeat frequencies (165.6-224.2 Hz) when compared to aphids. When comparing whiteflies and aphids to other insects, more massive insects have significantly and positively correlated wing loading and wingbeat frequencies, indicating that they, like other flying animals, compensate for high wing loading by increasing wingbeat frequency. This was not true for smaller insects such as whiteflies and aphids. Flying strategies for these smaller insects are believed to be different, e.g., whiteflies are known to employ a "clap and fling" strategy.

3. **Significance**

High reproductive rate and multiple host sequences provide optimal conditions for SPW population development. The varied habitats, seasonal population development and intra and inter-crop and wild host movement present an extremely complex and difficult challenge requiring new and innovative approaches for formulating control and suppression methodology. These control

methodologies must be based on a thorough understanding of the spatial and temporal features that drive the population dynamics of this insect.

Efficient sampling protocols will be essential to developing management systems that utilize pest monitoring as the basis for decision-making for pest suppression in a wide diversity of cultivated crops. A better understanding of the wild and crop hosts species important to SPW throughout the season should enable us to identify weak links in the seasonal cycle and then disrupt the host sequence that permits continual population growth and provides reservoirs for the transmission of plant pathogens.

Both intra- and inter-crop movement and longer-range migration are critically important in the epidemiology of plant viruses and in the distribution of SPW in multicrop ecosystems. Consequently, a better understanding of this phenomenon is essential in developing more efficacious control strategies that take advantage of weak links in the seasonal cycle of SPW. Understanding the factors that trigger movement should enable us to manipulate its timing as a means of control. For example, early termination of irrigation water to cotton may result in premature migration at a time when vegetables are not available for colonization. Alternatively, it may be advisable to chemically defoliate cotton before whitefly populations can reach maturity and migrate. Information concerning the migratory process will enable growers to make more informed decisions concerning such matters as selection of the most suitable variety, crop spacing, and crop sequencing.

Finally, incorporating our knowledge of population dynamics and dispersal into population models will provide an important organizational framework for on-going and future research. Additionally, the integration of these models with crop and pest management tools should aid development of management strategies that minimize pest impact and maximize crop productivity within the agricultural community.

4. **Cooperators/Co-Investigators**

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TABLE A. Ecology, Population Dynamics, and Dispersal

Research Approaches	Year 1	Year 2	Year 3	Year 4	Year 5
A.1 Define biology, phenology, and demography of SPW on greenhouse, field crop and wild host plants.	Systematic study of SPW on cultivated and weed hosts, seasonal time of occurrence, habitat.	Identify preferred hosts, determine seasonal distribution, determine developmental, reproductive and mortality rates of SPW on crop and weed hosts.	Continue demographic studies, determine relationships between crop sequencing, preferred hosts and population dynamics.	Determine seasonal contribution of cultivated and wild host plants to SPW population dynamics.	Describe role of cultivated and wild host plants on the population dynamies of SPW, identify weak links in seasonal biology.
A.2 Develop efficient SPW sampling plans for research and decision making purposes	Determine spatial distributions, define sample units for immature and adult SPW, examine variance components, optimize sample number and allocation.	Formulate sampling plans, determine relationship between sampling techniques for adults and crop infestations, evaluate feasibility of a standard sampling technique.	Continue development and refinement of sampling plan, implement and test protocols, develop remote sensing tools to estimate regional population levels.	Continue testing and implementation of sampling plans in terms of reliability and efficiency, continue development of remote sensing tools.	Finalize sampling protocols.
A.3 Develop economic thresholds for SPW in relation to feeding damage, honeydew production and virus transmission.	Determine components of yield and quality affected by SPW feeding, virus transmission and honeydew production on crop studied.	Determine and quantify relationships between SPW population density and plant yield and quality, formulate economic thresholds in relation to sampling protocols.	Continue quantification of relationships between SPW density and yields and quality, continue formulation of economic thresholds with refined sampling protocols.	Perform economic analyses, evaluate economic thresholds in crops studied.	Continue economic analyses.
A.4 Develop and test population models to describe and predict SPW dynamics.	Determine model goals, define preliminary model structures and identify data needs, evaluate existing biological information.	Develop relationships between SPW biology and crop phenology and crop sequencing. Integrate SPW, natural enemy, and plant components into simulation models.	Continue model construction, evaluate data needs, begin evaluation of model predictions of SPW population development.	Validate simulation models under field conditions, analyze model behavior.	Identify existing information gaps in insect and plant interactions.

A.5 Determine factors influencing SPW dispersal.	Determine relationships between crop phenology, crop status and SPW dispersal.	Determine biological factors (physiology, behavior, sex, etc.) influencing dispersal.	Determine effects of weather parameters on dispersal.	Examine interrelationships of crop production methods and SPW dispersal.	Summarize information on research progress on SPW dispersal and propose needed research.
A.6 Determine impact of dispersal on population dynamics in greenhouse, field crop, and weed host systems.	Develop marking methods (immunological, rubidium, genetical), determine population development and phenology on various crops.	Conduct mark-release studies-recapture studies, quantify seasonal intercrop and weed movement, determine influence of host sequencing and spatial patterning on SPW population development.	Continue quantification of SPW movement and determination of host sequencing and spatial patterning, integrate information into population models.	Continue as in Year 3.	Exploit potential of information developed on managing SPW dispersal as a control methodology.

B. Fundamental Research - Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions

1. Introduction

Although *Bemisia tabaci* has been recognized since the turn of the century as a phytophagous pest, and shortly thereafter as an important vector of plant viruses, the insect has only recently become of international concern as the transport of plant materials and exportation of fiber and vegetable products has become increasingly more global in nature. Important changes in agricultural practices, and the need to meet world food demands have likely precipitated the change in status of *B. tabaci* from a member of the endemic fauna to that of a major deterrent to agricultural productivity.

The taxonomic synonymization of at least eighteen designated worldwide species of *Bemisia* into the single genus and species, *B. tabaci*, translates into the realization that this polyphagous insect or assemblage of closely related insects is worldwide in distribution throughout the tropical/subtropical latitudes with a reported host range comprised of greater than 500 plant species. In earlier reports from tropical regions, host-related affinities or preferences among local populations, termed "races," or "biotypes" of *B. tabaci* were described. Experimental evidence for the concept was derived from studies designed to ascertain biological host ranges of regionally important plant viruses. In the context of these studies, it was not always possible to determine virus host ranges because laboratory colonies of *B. tabaci* could not survive on certain test plant species long enough to transmit the virus in question. Thus, successful feeding and subsequent reproduction were recognized as essential to the compatibility of the whitefly-host interaction, and, in most cases to the transmission of the virus. At times, however, continuous exposure to a plant species by a *B. tabaci* population with strong host preferences resulted in the ability to colonize additional hosts. Thus, the terms race, or biotype were used to refer to populations with recognized host preferences. These data were considered inferential due in part to the lack of corroborating information on genetic polymorphism, or distinguishing morphological characters.

Recent studies in Africa, Columbia, Israel, and in the United States have prompted a renewed interest in the concept of biotypes of *B. tabaci*. The coincidental emergence of the so-called "new poinsettia strain" or "B" biotype" in the US, and the resulting impact on agricultural and horticultural productivity have reaffirmed the need to understand more about fundamental differences between populations of *B. tabaci*. Fundamental knowledge of the biology of SPW is generally lacking, and is essential for identifying research approaches leading to effective, efficient socially and environmentally acceptable control strategies.

Polymorphic characteristics and genetic diversity of SPW and/or conspecific whiteflies, and basic biological, behavioral, biochemical and physiological factors are critical elements that must be understood to develop biorational

control of this pest. The adaptation of SPW to its plant host involves a complex array of insect-plant interactions affecting metabolic processes in both the whitefly and its host. Host plant selection, nutrient requirements and utilization, and feeding behavior are factors that relate to specific mechanisms of host plant resistance. Understanding virus-vector relationships, the relationship between feeding behavior and virus transmission, and solving problems involving SPW mediated disease agents and conditions require fundamental research targeting molecular interactions of the plant host, virus, and insect vector. Developing control strategies to protect economically important plants supporting SPW populations is dependent upon an understanding of many fundamental aspects of SPW biology: the genetics of SPW population dynamics, the relationship of endosymbionts to SPW fitness, the relationship of haplo-diploid SPW reproduction and infection development, the genetics of biotype formation, SPW ultrastructure, the molecular mechanisms of host-plant resistance, and the physiology of host acceptance and utilization, and the feeding process.

The very broad area of SPW behavior and the possible role of semiochemicals in SPW behavior mediation and host plant finding is incompletely explored. In addition, the influence of host plant characteristics of SPW behavior and population dynamics is not well studied. Understanding these interactions and influences are vital to pest management success and host resistance breeding programs.

2. Research Accomplishments

Virology and Epidemiology. Plant viruses transmitted by whiteflies cause over 40 diseases of vegetable and fiber crops worldwide. In the past decade, whitefly-transmitted (WFT) plant viruses have increased in prevalence and distribution. The recent impact has been devastating with yield losses ranging from 20 to 100 percent, depending upon the crop, season, and prevalence of the whitefly among other factors. Although WFT plant viruses and other whitefly-associated disorders are implicated in many additional instances, the pathogens have yet to be isolated and characterized; thus etiologies remain uncertain. Methods for virus detection and identification must be developed, and a greater understanding of virus relationships is essential for development of broad spectrum virus resistance.

B. tabaci had been recognized as a sporadic pest on cotton in subtropical Mexico and the southwestern U.S. deserts (Arizona, California, and Texas) during the 1950s and cotton leaf crumple disease was documented for the first time. Similar observations were made concurrently in Cuba and throughout the Caribbean basin. By the late-1980s, the insect had become a serious pest and virus vector in cotton, cucurbits, lettuce, pepper, and tomato throughout these regions. As could be predicted from earlier trends in the tropical regions, WFT viruses subsequently became commonplace in many vegetable crops, and are presently responsible for epidemics to which millions of dollars are lost annually. Thus, during 1980-1990, nearly every fiber and/or vegetable producing country in the tropical and fringe temperate latitudes of the Americas

and Caribbean Basin has experienced high-level infestations of *B. tabaci* and serious disease losses now routinely associated with WFT geminiviruses. There are indications that viruses representing several other families may also be involved. In addition, several new phytotoxic disorders associated with feeding by *B. tabaci* nymphs and adults were reported in cole crops, tomatoes, squashes, and cucurbits in the U.S. and Caribbean Basin. The squash silverleaf and uneven ripening of tomato disorders were first documented in Florida (U.S.) in 1987, and have subsequently been observed in Puerto Rico, the Dominican Republic, The Eastern Caribbean, the Southwestern U.S., and Hawaii. Phytotoxic symptoms termed "white streaking" occurred for the first time in several cole crop species grown in the southwestern U.S. in the winter of 1990-91. In addition, chlorosis and stunting was associated with tropical fruits such as papaya in Hawaii and the Caribbean basin, and in many ornamental species of shrubs and trees infected by SPW throughout the region.

Among the 1,100 recognized species of whiteflies in the world, only three are recognized as vectors of plant viruses. *B. tabaci* is now recognized as the most common and important whitefly vector of plant viruses worldwide, and it is the only known whitefly vector of geminiviruses. Diagnosis of WFT geminiviruses requires a laboratory assay which must corroborated by tedious biological characterization.

These limitations mandate a time consuming multi-faceted diagnostic approach, particularly when previously unrecognized WFT geminiviruses are involved. DNA-DNA hybridization assays which utilize broad spectrum DNA probes are most effective in detecting and confirming infection by WFT geminiviruses. Very few virus specific probes are available, however, because only sporadic efforts have been made to investigate and characterize the plethora of virus isolates currently recognized as potential pathogens in the region. Since new virus diseases were first noted in tomato and pepper crops in 1987-88, only limited resources have been devoted to improved diagnostic technologies, based upon fundamental knowledge of the composition and organization of viral genomes and on virus encoded polypeptides.

The ecology of plant viruses is complex subject. The biology of many viruses is essentially unknown. Sampling methods need to be designed specifically for virus epidemiology studies. In addition, knowledge of realistic damage thresholds from SPW are needed for crops affected by SPW-vectored viruses.

No strategy for control of WFT geminiviruses has been proven effective in practice. Whiteflies are difficult to control with insecticides, and development of pesticide resistance in whitefly populations has occurred frequently. The lack of other reliable means for reducing vector populations has compounded the problem. Barriers such as row covers, and repellant mulches which affect phototactic responses of whiteflies, have shown some promise in delaying or reducing disease incidence, but are not useful when whitefly populations and virus inoculum levels are high. SPW management methods including weed control adjacent to cultivated fields, the use of trap crops, and implementation of

crop- free periods are effective in reducing vector populations in certain cropping systems. Conservation and augmentation of natural enemies in unmanaged SPW populations should also be encouraged. Long-term strategies and creative approaches are needed to reduce the losses currently sustained from WFT geminivirus infections.

Development of resistant varieties using classical genetic and plant breeding techniques is currently being pursued. Breeding specifically for resistance to virus, rather than focussing only on resistance to whitefly, warrants consideration. Several laboratories are applying biotechnological approaches to develop virus-resistant vegetable cultivars through approaches involving among others, coat protein-mediated protection, defective replicase interference, and various antisense strategies. The incorporation of both classical and engineered types of resistance into a single cultivar would likely reduce the potential for breakdown of either type of protection.

Taxonomy and Biotypic Variation. The systematics of whiteflies has been problematic. In particular, the taxonomy of *B. tabaci* has been difficult to reconcile due to the extreme plasticity of key morphological characteristics which are capable of change to accommodate morphological features of the host plant. As a result, eighteen described *Bemisia* species were synonymized to the binomial, *B. tabaci*, resulting in the recognition of a single, polyphagous whitefly species which inhabits suitable ecosystems on every continent between the 30th parallels, north and south. These boundaries have now been extended to include regions in fringe temperate zones as well following the introduction and dispersal of what has been termed biotype "B". The systematics of the entire genus of *Bemisia* is clearly in need of revision.

The differential propensities of *B. tabaci* populations to colonize a specific host species has been documented on several occasions. Two biologically distinct *B. tabaci* biotypes were recently described in Ivory Coast based upon host preferences and different isozyme patterns. These populations coexist in the same region, one affiliated with cassava and eggplant, while the other infests okra and other locally available species. A similar scenario occurs in Puerto Rico, with distinct races on Jatropha and Sida. In Israel, isozyme differences were documented for several populations of agricultural importance, and variability was attributed in part to differential pesticide resistance. Similar analysis of populations in Columbia revealed differential isozyme patterns for *B. tabaci* collected from distinct geographic regions which are delineated in part by the Andes Mountains.

In contrast, a new biotype or taxa with a broad host range and high fecundity on numerous ornamental, fiber and vegetable crops has recently become of paramount importance in the US and Caribbean Basin since 1986-87 following dispersal on plant materials, and apparent establishment on available host plants. In addition to differential host range characteristics, this "biotype" is distinguishable from the pre-1986 SPW populations traditionally infesting bean, cotton, cucurbits, and other crops in the region based on a distinctive

non-specific esterase pattern, and by the ability to induce phytotoxic disorders in Cucurbita species, cole crops, tomato, and other host plants. Based upon characteristic, host-and geographically- independent esterase markers, the putative biotype associated with poinsettia and cole crops has been termed the "B" biotype, while the historically pre-1986, cotton-derived population is termed the "A" biotype. Although the origin of this new taxa or biotype is presently unknown, there is strong evidence for the introduction of an exotic *B. tabaci* population. The origin of type "B" SPW has not been determined, but speculation has centered on Near- or Far-eastern Asia. A search for the true origin of type "B" can be conducted with methods for distinguishing between unique populations and samples collected from populations around the world. An examination of the host range may provide clues useful in directing the search. Increased knowledge of type "B" ecology, physiology, host plant relationships and improved chances of identifying effective biological control agents should result if the origin can be identified.

The lack of information on whitefly behavior, biology, genetics, and physiology and the lack of reliable distinguishing morphological characters has limited the utility and application of the terms biotype, race, or strain to *B. tabaci* as an insect pest species. Presently, it is not known whether differences in *B. tabaci* populations extemporaneously ascribed to plant host preferences arise as a result of nongenetic polyphenisms, or polymorphic or polygenic variation, and/or if geographical restrictions apply. Indeed, some *B. tabaci* populations may eventually be recognized as distinct species, some as host races, while yet others may be defined as geographic races with less dependence on host association. A greater appreciation of interspecific differences among whiteflies, and a more definitive understanding of the parameters and consequences of intraspecific variation are needed for *B. tabaci*. Nevertheless, the recent surgence of *B. tabaci* as an important virus vector and pest of a wide range of agricultural crops has likely provided the impetus to accomplish some of these goals, and thus learn more about fundamental aspects of whitefly biology, genetics, and important agroecological parameters.

Studies of SPW systematics currently underway encompass a variety of new and traditional methodologies, including DNA sequences, cuticular hydrocarbons, other waxes, isozymes, morphology of immatures, pupal cases and adults, relatedness of symbionts, and detailed morphometric analysis. Behavioral studies, including mating and cross breeding studies to determine the relatedness of different strains, are in progress. There is inadequate knowledge of differences between populations, strains, or other taxa of SPW worldwide as well as of the variability within these groups. Suitable methods for collection and preservation of samples to be used in these studies need to be identified. The need for a simple and quick method for identification of whitefly biotype, or taxon, is evident.

Genetics. Our understanding of SPW genetics is very rudimentary. There is no information on ploidy levels in adult or immature stages of SPW. Population

genetics studies of whiteflies would be very useful in further understanding various topics including pesticide resistance, biotype formation, and behavioral (migratory vs. trivial movement) morphs. Studies of the genetic variability of SPW in different regions of the world may shed light on the origin of biotype "B".

Resistance to several classes of existing chemical insecticides has been demonstrated many times in various populations around the world. A variety of enzymes have been found to be responsible for resistance. Recently it has been found that some insecticides synergize others, possibly by inhibiting esterases responsible for causing resistance. The basis for resistance has not been definitively explained although esterases (acetylcholinesterases) have been implicated. Resistance in biotype "B" SPW to thiodan has been reported in Florida.

Molecular Biology, Biochemistry, and Physiology. The crop disorders squash silverleaf (SSL) and tomato irregular or uneven ripening (IRR or UR) are both associated with the feeding of the SPW biotype "B". This biotype appears to contain unique nucleic acid in the form of double-stranded RNA (dsRNA) and there appears to be a relationship between the expression of dsRNA in the SPW and the induction of SSL. The significance and origin of this nuclear material is not yet understood. Electron microscopy has not yet revealed any virus or virus-like agents in plants affected with SSL. It has been shown that SSL and IRR are phytotoxic effects associated with a specific SPW biotype; cytological and physiological data show that squash cell development and senescence are directly affected by SPW feeding. It has been suggested that translocatable factors responsible for the systemic effects of the phytotoxemia may originate from host-whitefly interactions, as opposed to toxins produced by the insect alone. Another alternative explanation proposes that a viral agent as the cause has not yet been ruled out. The role of endosymbionts and naked nucleic acids (without a virus capsid) have not been investigated as potential causal agents.

The identification, isolation, and importance of endosymbionts of SPW in speciation or biotype formation and plant disorders is receiving attention. The role of such endosymbionts in SPW nutrition, competition, or other aspects of fitness is a completely new focus for investigation.

It has been assumed that whiteflies are phloem feeders, but this should be reevaluated using histological, morphological and biochemical techniques. There is evidence that some intracellular penetration occurs during stylet probing; the potential significance of these observations to feeding disorders and virus transmission efficiency has not been addressed. Further studies of feeding and nutrition are needed to establish nutrient allocation budgets and diurnal patterns of nutrient cycling. The constituents of phloem sap ingested by SPW and its excreta have been examined. Biotype "B" is capable of processing significantly more phloem sap than biotype "A"; perhaps allowing it to develop successfully on a wider range of hosts. In one study, some of the amino acids in host phloem sap were found in reduced form in whitefly excreta, suggesting they are

metabolized in the whitefly. Other amino acids may be important in nitrogen metabolism and excretion by SPW. In addition to other carbohydrates, a disaccharide sometimes associated with certain microorganisms but not previously found in insects, trehalulose, has been identified in "type B" honeydew.

Additional study of SPW physiological ecology is needed to identify the basis for the differential ability of the whitefly taxa or biotypes to colonize hosts in different climates. The influence of water stress, nutrients, and trace elements in the host should be examined.

Tolerance of hot and cold temperatures and overwintering of specific SPW biotypes have not yet been investigated but will aid in anticipating the eventual range within North America and the potential for range extension. The "B" biotype has been documented to date throughout portions of the United States, the Caribbean basin, Mexico, and is likely present in Central America as well. The ability to identify distinct SPW populations in other parts of the world will also be useful.

Behavior. There is a general lack of knowledge regarding host plant factors influencing host selection, suitability, and host switching by SPW. SPW is strongly attracted, like other whitefly species, to surfaces reflecting in yellow-green wavelengths at some times and to blue/UV reflecting surfaces at others. Several recent studies have examined the influence of host and host choice on SPW fecundity. In some cases, SPW eggs are deposited on plants apparently suitable for adult feeding but not conducive to survival of progeny. Earlier studies have failed to demonstrate olfactory response by SPW; however, studies of SPW behavioral response to different plant odors using an olfactometer have been initiated. Host acceptance or rejection seems to be largely due to taste response following short leaf probing into the mesophyll layer. The potential for SPW management by behavioral modification , at least at low population densities, is suggested by observations of repulsion of whiteflies from pesticide-treated crops. Other repellent materials could be identified with further research. Recent work in Israel suggests that the presence of conspecific whiteflies has no influence on SPW adult landing and host probing and acceptance behavior.

Knowledge of feeding behavior is currently limited. Ongoing research with electronic feeding monitors is beginning to examine feeding activity patterns, making correlations with external stimuli and behavior possible. These studies should result in increased understanding of SPW host selection, movement among host plants, and virus transmission efficiency.

Whitefly movement within and between plants, the resulting distribution of SPW, and effects of chemicals on distribution have been examined in greenhouses and in field crops. Two types of flight, local or trivial flight and long distance or migratory dispersal, have been postulated. Two distinct adult SPW morphs have been defined with morphometric analysis; it has been

suggested that they may possess differing tendencies to disperse. The stimuli which motivate whitefly adults to leave apparently healthy plants are not known.

Studies of mating behavior and the effect of mating on fecundity, viability, and population structure of SPW on cotton are in the literature. These types of studies need to be correlated with specific SPW taxa or biotypes, because host plant effects strongly influence these parameters. Mating behavior has been studied earlier and is apparently similar to that of greenhouse whitefly. SPW are haplo-diploid and reproduce by arrhenotoky. Unmated females produce only male offspring; mated females may produce varying percentages of female offspring dependent upon environmental influences which are not well understood. In Florida, recent studies of "type B" have been initiated, demonstrating that viability of eggs can be much lower from unfertilized female SPW. Oviposition during the first days of adult life is not influenced by mating history.

The existence of a sex pheromone has been reported for greenhouse whitefly. Evidence for a similar pheromone in SPW is not as clear cut, however some signs of attraction of males to females have been found and further studies are underway. Behavioral observations of type "B" SPW in Florida suggest the possibility of an arrestant produced by females. In Arizona, experimental observations indicate SPW adults avoid plants previously occupied by green lacewing, *Chrysoperla carnea* Stephens, suggesting allelochemical communication mediation.

Inter- and intraspecific competition in SPW has not been extensively studied. Studies of intraspecific competition between SPW taxa or biotypes would be useful in predicting the spread and impact of different populations. Although there is general agreement, based upon observational data, that SPW is an effective interspecific competitor in warm or hot climates, competition between SPW and other whiteflies has received only limited attention to date. Competition and other interactions with other plant pests such as aphids and mites has not been examined. Much more work remains to be done. Other important gaps in knowledge include the mechanisms for diurnal rhythms and seasonal changes in behavior, population dynamics, dispersal, etc.

Trophic Level Interactions. Studies of trophic level interactions between plant host, SPW, and its natural enemies are not numerous to date but several research groups are interested in exploring this area. Investigations with tomato, cotton, and poinsettia are now underway. Many other important crops need to be studied as well. Understanding how SPW is able to adapt to new host species is a major gap in our understanding.

The biochemistry and the surface structure of the plant host may strongly influence survival and developmental parameters of SPW. For example, glandular hairs may produce secondary plant compounds toxic to SPW, while non-secretory hairs are usually thought to offer SPW immatures protection against searching natural enemies. Surface features may also influence the microclimate at the leaf surface. Cuticular waxes are thought to inhibit

germination of fungal pathogens of both plants and plant pests. The influence of host plant chemistry on SPW natural enemy development and behavior is even less well understood. The reciprocal interaction of host plant and SPW feeding should be clarified; such studies will aid in understanding processes of virus inoculation and development of host disorders. In addition, susceptibility of SPW to pesticides may be altered by phytochemical synergists and metabolic inhibitors.

3. **Significance**

The lack of information regarding the complex genetic, morphological, physiological, biochemical and physiological, behavioral, and ecological relationships in SPW necessitates research to provide new information leading to a more complete understanding of fundamental SPW biology. Increased knowledge of these areas will benefit our understanding of host plant interactions, natural enemy interactions, ecological interactions and logical approaches to SPW management.

Determination of the origin, and the degree and nature of relatedness of different populations of SPW and the factors contributing to its rapid geographic and host plant radiation may give useful insights into mechanisms that could be exploited for managing the whitefly. There is a fundamental need for molecular identification services. Such services are available for differentiating morphologically distinct taxa, but are unavailable for taxa that can be distinquished with molecular characters. This situation slows the progress of research in laboratories lacking molecular systematics capabilities.

Detailed systematic knowledge of *Bemisia tabaci* and all species of *Bemisia* is critical for implementation of a framework for hypothesis testing. Basic taxonomic information should provide predictive data on areas of origin, host plant relationships, natural enemy associations, etc. This work should encompass as many different character systems as possible including morphological, behavioral, molecular, and symbiont associations.

Defining the mode and site of action of whitefly feeding, phytotoxic compounds, salivary secretions, and enzymes associated with specific SPW biotypes will determine how such molecules affect host plants and resistance. The influence of the feeding process on the ability of SPW to vector virus needs to be studied. The association of these SPW biotypes with new plant viruses and disorders such as SSL compounds the problem and makes adequate control and pest management strategies difficult with current knowledge.

Quantifying the relation between SPW population levels and virus disease prevalence and distribution will also be useful in determination of acceptable levels of whitefly in different crops. The importance of crop age and the percentage of viruliferous adult SPW in a population must be considered within the context of specific cropping systems. Understanding the potential and

existing threats to agricultural production as a result of virus infection must also be a priority.

There are currently no available comprehensive or standardized means for virus identification and many of the recently emerging viruses remain uncharacterized. An obvious need exists to develop efficient genomic and serologically based methods for rapid virus identification and for cataloging the viruses which occur in the United States, Caribbean basin, and in adjacent regions with whom trade is conducted. A knowledge of "who the enemy is" with respect to plant viruses is needed to assess the potential risks associated with sending and receiving shipments of vegetatively propagated food and ornamental crops, nursery crops, cut flowers, vegetable transplants, and other plant materials which serve as hosts of SPW and SPW-transmitted viruses. Further, it is imperative that studies be conducted to determine the vectoring capabilities of SPW occurring on other continents and in other regions and states in light of the potential for introduction of persistently transmitted viral pathogens by SPW infesting a variety of food and ornamental crop species, regardless of whether the infested plant species serves as a host of the particular virus. There is the obvious potential for introduction of viruses into the United States and elsewhere if these aspects are not taken into account. Etiology has been demonstrated for only a few of the newly recognized virus-like diseases which have emerged in epidemic proportion in the U.S. and Caribbean basin during the past decade. Information is needed concerning biological and molecular characteristics of new viral pathogens, virus-vector relationships, modes of transmission, epidemiological parameters (sampling methods, environmental parameters, cropping systems, vector population dynamics, host selection), the impact of biotypic differences on virus transmission and spread of disease, molecular mechanisms of transmission and virus- vector specificities, natural cross protection, mixed infections and other potential synergisms, and other factors which affect the status of the disease situation. Pure cultures of viruses must be established to effect biological characterization and transmission studies, and to provide purified virus for production of virus antibodies needed for serologically-based diagnostics. Viral genomes must be cloned and sequenced to accomplish molecular characterization and genome organization. Nucleotide sequences are needed for comparative studies, in order to design virus-specific probes, and to provide the necessary viral genes for development of classical and/or engineered resistance. Infectious clones are needed to investigate the consequences of mixed infections synergism with unrelated viruses, cross protection events, and the potential for pseudorecombination between viral genomes which could result in the creation of new or hybrid viruses with different properties. Both classical and engineered methods must be explored to identify sustainable sources of virus resistance, and to develop resistant varieties having desirable horticultural characteristics and which are adaptable to a wide range of climatic pressures, cropping systems, and industry needs. Mechanisms of resistance must be investigated and the potential for broadspectrum protection against several representative prototypes from different world regions must be investigated.

Elucidation of molecular modes of action associated with SPW resistance will allow traditional breeding programs to target the enhancement of specific endogenous plant defense systems and define mechanisms for biotechnology-based development of resistant stock. Developing specific molecular markers and studying endosymbionts associated with individual biotypes will lead to insight into the mechanism of biotype or species formation and the genetics of SPW population dynamics.

Knowledge of SPW behavior, including host plant selection and host adaptation, is a key component of basic knowledge. Advances in this area will directly benefit additional applied research for management of whiteflies as direct pests and as virus vectors.

The potential use of semiochemicals in insect management systems that relate to survey, detection, sampling, host finding and reproduction are well accepted. Little or no information has been developed in these areas of behavioral mediation in the SPW. Recent work suggests that sex pheromones or other attractants may exist. There is an urgent need to investigate the existence of pheromones, kairomones, allelochemicals and their influence on SPW population development. The influence of other natural products with behavior modifying activity needs to be investigated, including host plant secondary compounds, and kairomones utilized by natural enemies.

Studies of trophic level interactions and semiochemicals of other insects have provided basic insights with applications to plant breeding, habitat management, pesticide efficacy, and other agronomic practices which influence pest populations and natural enemy efficiency. Although trophic interactions may be complex and difficult to generalize, significant insights will be obtained with additional research.

4. **Cooperators/Co-investigators**

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TABLE B. Fundamental Research - Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions

Research Approaches	Year 1	Year 2	Year 3	Year 4	Year 5
B.1 Studies of feeding behavior: sensory receptors, ultra-structure, morphology, digestive physiology; intra- and interspecific competition.	Begin studies of ultrastructure, morphology; analyze feeding and digestive processes; begin studies of parameters influencing competition.	Continue studies from Year 1; characterize feeding by-products and digestive enzymes; determine influence of host plant morphology, physiology, ecology and phenology on SPW feeding behavior and competition.	Continue in-depth studies begun earlier; investigate relationship between endosymbionts and nutrition; use feeding monitor to screen for host resistance and response to residues of pesticides and natural products.	Continue research begun earlier; identify weak links for management-based research.	Continue basic research; investigate approaches for interrupting feeding and digestion, and reducing competitive abilities.
B.2 Studies of biochemistry, physiology, nutrition, development and reproduction, genetics and genetic diversity.	Identify temperature tolerances; begin study of host influences (i.e., water balance, osmotic concentrations, nutrients) on SPW; begin studies of nutritional physiology, reproductive physiology, ploidy level.	Continue fundamental studies begun in Year 1; expand studies of genetic diversity; identify areas for continued emphasis.	Continue basic studies; identify potential weak links for further research: i.e., genetic and physiological bases for host selection, habituation, switching, etc.	Continue basic studies; investigate approaches for interrupting or altering key biological processes.	Continue basic studies; implement strategies for interfering with key processes; assess potential for further development.
B.3 Studies to discover and analyze diagnostic characteristics of SPW, including component taxa, and to determine biological and genetic basis for development of biotypes, host races, and species.	Collect SPW taxa and characterize their validity using morphological, molecular, biochemical, and biological studies to distinguish genetically different populations; develop voucher protocol for preservation of morphological and molecular information; establish centralized molecular services.	Continue systematic analysis of SPW; provide molecular services based on information derived from Year 1.	Continue systematic analysis of SPW; develop rapid identification systems.	Finish analysis of SPW character development of rapid identification system.	Provide synthesis of diagnostic analysis of SPW taxa; relate results to other fundamental approaches; continue molecular identification services; finish development of rapid identification system.

B.4 Develop systematic analysis of the genus *Bemisia* utilizing various methods.	Begin analysis of all species of *Bemisia* using at least morphological and DNA sequence analyses; develop collecting and preservation protocols; identify sources worldwide and begin collecting material for analysis.	Continue analyses of *Bemisia* species, defining characters using characters from morphological and DNA sequence studies; investigate value of supplementary methods (i.e., cuticular hydrocarbons, immunological assays, isozymes, symbiont associations, etc.)	Continue analyses of *Bemisia* species, define taxa and begin phylogenetic analysis.	Complete systematic analysis of *Bemisia* species; complete phylogenetic analysis of at least morphological and DNA sequence information.	Complete systematic analyses; validate supplementary methodologies.
B.5 Identify and define SPW toxicogenic effects. Develop dsRNA and cDNA probe.	Characterize toxicogenic effects, cytology and EM.	Fractionate SPW and affected plants. Isolate toxicogenic fractions. Characterize endogenous mediators, Use cDNA probe to screen biotypes.	Define affected plant target molecules and molecules mediating systemic response. Use probe to localize source of dsRNA.	Characterize toxicogenetic molecules and mode of action. Utilize probes for field IDs.	Define mechanisms of plant resistance and integrate knowledge in developing IPM.
B.6 Characterize SPW endosymbiote (SPWe) influence on metabolism, host range, and biotype formation.	Treat SPW with antibiotics and determine effects on growth, development and reproduction.	Develop methods for isolation and SPWe and extraction of nucleic acid. Amplify specific SPWe genes via PCR.	Analyze variability of SPWe genome in different SPW biotypes via RFLP, PFE and hybridization with SPW dsRNA probe	Determine specific genes and gene products associated with SPW metabolism.	Analyze progress and determine feasibility of pest management based on interruption of endosymbiotic relation.
B.7 Investigate etiology of diseases; biological and molecular characterization of causal agents; develop understanding of relationship; molecular probes for viral diseases; diagnostics and resistance; virus-vector specificity and interactions.	Collect and establish pure cultures; initiate transmission studies and biological characterizations, cloning and purification for these studies and antibody production, screening for resistance.	Continue with biological and molecular studies; continue cloning and characterization; begin antibody production. Develop detection and identification systems. Study virus-vector interactions: receptors, transmission, transformation, resistance.	Continue developing virus diagnostics; molecular comparisons of sequence data, relations; continue cloning and characterization; continue virus-vector studies. Develop diagnostic tests for epidemiological purposes; clones for (injured) resistance.	Develop strategies for engineered resistance; prototype isolates based upon molecular characterization and distribution studies; biological, molecular parameters, viral designations standardized; methods for identification; mechanisms of vector transmission.	Continue virus-vector studies; evaluate resistance studies: engineered and classified w/prototype isolates. Continue biological and molecular studies of new pathogens; viral taxonomy; standardize names.

B.8 Study epidemiological parameters: vector population dynamics; disease thresholds; identify sources of inoculum, distribution, severity, and prevalence of pathogens. Correlate efficiency of transmission with biotypes, diversity and parameters of cropping systems.	Initiate study of transmission efficiency, vector population dynamics, fecundity studies, host reservoir studies. Survey problem areas to identify key virus isolates; develop transmission thresholds for viruses.	Continue to investigate epidemiological parameters; begin to establish diagnostics; identify key isolates for in-depth characterization; study vector-host plant interactions.	Continue epidemiology studies; evaluate strategic management methods (i.e., sanitation programs based on inoculum sources); study vector-host-virus interactions in field; apply diagnostics.	Continue application of diagnostics to field epidemiology studies. Evaluate distribution, reservoirs using diagnostics; evaluate resistance in field studies.	Continue development, application of management strategies based on epidemiology studies. Transfer information for use in cropping systems, host free periods, recommendations for long term disease management.
B.9 Study mating and oviposition behavior.	Study mating behavior in detail; determine possible role of sex pheromone; study role of mating in oviposition.	Determine factors, environmental and biological, that affect mating; determine factors affecting oviposition site selection and fecundity.	Develop methods for determining mating success, sperm transfer, fertilization, etc.; determine role of nutrition in oviposition and viability.	Identify factors that may be manipulated to manage or present mating; examine potential of attracticides and manipulation of crop production in reducing oviposition.	Exploit such factors in field trials to determine their potential in control methodology; quantify role of oviposition behavior in population dynamics.
B.10 Determine factors influencing host plant selection and host acceptance.	Determine nature of physical, environmental, plant host, physiological cues involved; investigate extent of semiochemical mediation in host finding.	Isolate, identify chemicals and other cues involved; continue studies of host selection and acceptance.	Develop bioassay methodology for quantifying semiochemical effects on SPW behavior.	Determine interactions of semiochemicals with environmental factors, incl. natural enemies.	Determine potential for manipulating semiochemicals and other host-finding or acceptance cues as behavioral components in SPW control systems.
B.11 Identify plant nutritional and defensive responses to SPW and their effects on SPW and natural enemies.	Identify proteins, enzymes, and natural products induced in plants by SPW; examine influence of changes in nutrient levels on SPW and enemies.	Isolate and characterize induced protein, enzymes, or compounds.	Determine effects on SPW and evaluate as resistance mechanism; evaluate effects on SPW natural enemies.	Identify source of defensive factors in plants and their targets in SPW; continue studies of tritophic level interactions.	Target specific factors for genetic engineering of plant resistance.

C. Chemical Control, Biorationals and Pesticide Application Technology.

1. Introduction

Conventional chemical control of the SPW is difficult to achieve because of the distribution of the immature forms primarily on the underside of leaves, with older larvae and pupae located lower in the plant canopy. The diversity of the cultivated and weed host plants attacked contribute to the source of infestation. Although a number of insecticides have effectively controlled SPW in the past and several new materials, including systemics, appear promising. The resistance phenomena suggest that their efficacy will be of limited duration. Resistance monitoring and insecticide resistance management systems must be developed and implemented to extend the effective life of existing and new materials. At present, knowledge of the genetics and mechanism(s) of resistance is limited. This information is essential for the development of insecticide alternative use patterns as well as finding new materials with different modes of action.

2. Research Accomplishments

Chemical Control. Over 40 pesticides or pesticide combinations have been evaluated in greenhouse, laboratory and field trials for control of the sweetpotato whitefly. Greenhouse and laboratory trials included lifestage specific evaluation whereas those in the field were with mixed lifestages. Products tested by researchers included organochlorine, carbamate, organophosphate insecticides and selected pyrethroids and IGR's. Products in all classes were found effective in laboratory studies but not all were effective in the field. Certain combination of pyrethroids and organophosphates appear to be synergistic. Some success has been reported with systemic insecticides, but additional studies are needed to determine efficacy in management systems.

Biorationals. Organic and inorganic materials with completely different modes of action than conventional insecticides have been identified as effective against the SPW. Oils have been used as insecticides, acaricides or as additives. They are considered to be physical poisons that interfere with respiration in arthropods, although some plant oils may contain toxicants. Both petroleum based and plant derived oils have been reported efficacious against all stages. Soaps and detergents, either synthetic or naturally derived are active against all life stages except eggs. Botanical extracts such as azadirachtin from neem seed and glandular secretions from species of *Nicotiana* are highly toxic to nymphs. The modes of action of these plant derived chemicals are unique. For example, azadirachtin has IGR-type activity whereas extracts from selected *Nicotiana* species appear to affect the cuticular lipids that control water loss. Repellency from species of *Nicotiana* has also been observed that suggest a plant volatile may be involved. Inorganic materials such as diatomaceous earth may merit examination of application method and efficacy.

Pesticide Application Technology. Research must produce methods to improve canopy penetration and to selectively provide better coverage on the underside of leaves should result in increased chemical control efficiency. Application technology must be developed to provide toxicant coverage in the area of the target SPW habitat. Timing, rotations and rates of application must be developed with existing insecticides and insecticides with new chemistry or new modes of action to provide protocols for insecticide and SPW insecticide resistance management. Application comparisons must be made for improvement of existing ground and aerial application equipment and techniques. New technologies such as air-assisted and air-curtain booms and electrostatic precipitation devices must be tested and evaluated. Non-conventional chemigation for pesticide application such as trickle irrigation for systemics and in-canopy sprinkler irrigation with modified spray nozzles should be evaluated. Efficacy should be determined for the application methodologies that provided the most effective deposition attributes.

3. **Significance**

a. Current reliance on chemical control must be considered to be a temporary measure until satisfactory IPM programs can be developed. Preliminary studies have identified new insect growth regulators and new pyrethroid insecticides that appear promising. Materials with completely different modes of action against immature SPW have been identified.

b. SPW economic thresholds must be determined. Then, application schedules and methods must be developed in relation to them to minimize insecticide use and improve efficacy. Studies need to be initiated to: 1) develop SPW insecticide resistance management programs, and to develop and outline area-wide pesticide rotation systems to maintain a broad range of pesticide options for SPW control, 2) provide protocols for detecting and characterizing the genetic basis for resistance, and to identify resistant and susceptible strains including common reference strains to identify effective alternatives, and 3) determine the impact of insecticides on natural enemies as part of the standard evaluation procedure.

c. The best materials with the highest potential should be identified and evaluated for: 1) efficacy and sequencing with other chemicals, and 2) for determination of their impact on natural enemies.

d. Chemical and biorational application technology must develop improved methods for delivery of materials to improve control.

4. **Cooperators/Co-investigators**

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TABLE C. Chemical Control, Biorationals and Pesticide Application Technology.

Research Approaches	Year 1	Year 2	Year 3	Year 4	Year 5
C.1 Identify for registration, new chemicals and formulations that effectively control SPW.	Lab and field evaluation of chemicals with rates, combinations to identify promising materials.	Expand field research with best combinations and application methodology.	Evaluate new chemicals in relation to stage of insect killed, economic threshold, and effect on beneficials.	Determine chemical effects of SPW populations, increased yields, and quality of crops to provide data useful for registration purposes.	Formulate control strategy based on research progress that indicates rates, gal/ acre, frequency of application, and associated secondary pests.
C.2 Identify for registration, biorational materials with new modes of action.	Initiate studies with oils, soaps, natural products, both organic and inorganic, to determine efficacy.	Conduct field studies to determine coverage, rates, gal/acre, etc., to provide data useful for registration purposes.	Expand studies with best materials with highest potential. Evaluate efficacy, timing, alternatives with other chemicals.	Develop alternating sequences between chemicals and biorationals for best SPW management system.	Implement alternating sequence management systems to prevent resistance.
C.3 Develop application schedules and methods in relation to economic thresholds.	Determine SPW population levels under various chemical and biorational control systems.	Determine relationship between SPW populations, chemical control, and yield for economic threshold.	Identify specific optimum controls in relation to SPW economic threshold.	Validate estimated economic threshold concept and insecticide use patterns.	Develop protocols for SPW economic thresholds and insecticide use on as-needed basis.
C.4 Insecticide resistance studies.	Collect strains in different locations, crops, etc., and establish resistance patterns and levels.	Develop standardized insecticide resistance monitoring systems.	Determine insecticide dose relationships, discriminating doses, and hormoligosis.	Initiate study to determine mode of action of insecticides.	Initiate studies to develop insecticide resistance management and outline area-wide pesticide rotation systems.
C.5 Genetics of insecticide resistance in SPW.	Collect strains in different locations, crops, etc., and establish resistance patterns and levels.	Begin construction of isogenic resistant and susceptible strains through back-crossing and selection.	Use RAPD and restriction mapping techniques to ID markers associated with resistance genes.	Isolate individual resistance genes in back-crossed lines and determine cross-resistance relationships.	Initiate studies to develop insecticide resistance management and outline area-wide pesticide rotation systems.

C.6 Develop methods for application or delivery of materials to improve control.	Compare methods of application, e.g., aerial, ground, high volume air, and others for estimates of plant (especially underleaf) coverage. Determine spray deposition (μg a.i./cm^2) and coverage for different application techniques, e.g., aerial, ground, electrostatics, chemigation, air carrier sprays, etc. Relate efficacy to spray deposition and coverage.	Evaluate modified spray equipment, boom drops, nozzles, and arrangements; and chemigation.	Determine efficacy, with best coverage application equipment.	Verify best of the current state-of-the-art application equipment.	Determine need for continued research.
C.7 Evaluate application methodologies for impact on natural enemies and SPW interactions.	Determine baseline information on existing natural enemies-quality and quantity.	Determine effect of various chemicals and biorationals on natural enemy populations and associated minor pests.	Compare rates, combinations, application technology on natural enemy populations.	Determine optimum and best materials and application technology to develop maximum natural enemy conservation.	Develop standard protocols for chemical control and natural enemy integrated systems for best control in relation to economic thresholds.

D. Biological Control

1. Introduction

Numerous natural enemies of *Bemisia tabaci* have been recorded from many parts of the world, but little is known about the resident natural enemy complex in the southern USA. It is expected that once these regions are surveyed, potentially valuable natural enemies of *B. tabaci* will be discovered. Many candidate species from other areas are also available for possible importation but biological information about many of these species is lacking and resources for exploration, collection, quarantine rearing and both laboratory and field evaluations have been inadequate. A concerted effort is being made to manage *Bemisia* in many parts of the world where it has become a problem including North America and recent interest in biological control has been high. In the southeast USA, the whitefly biological control efforts of many scientists are being coordinated through a regional project entitled "Biological Control of Selected Arthropod Pests and Weeds Through Introduction of Natural Enemies". This project is ideally suited to serve as a mechanism for the coordination of this important research thrust. Coordination of this particular objective is critical if we are going to be successful. This is particularly important when we begin to make field releases. As scientists in California have pointed out, the uncoordinated release of parasites could jeopardize the eventual establishment of adequate control. The release of an agent simply because it is available, without appropriate research and planning for an overall campaign strategy, is shortsighted, inappropriate and possibly dangerous.

2. Research Accomplishments

The role of natural enemies in regulating SPW populations is not well understood. Reports of natural enemy population regulation and suppression have been variable. Reported parasitoids (ca. 25) are in the genera *Amitus*, *Encarsia*, *Eretmocerus*, and *Pteroptrix* (this host record has been questioned as being a possible error). Many predators (ca. 30) have also been identified (in various families of Hemiptera, Coleoptera, Diptera, Neuroptera, and Acari). Assessment of parasite and predator activity is complex and variable. Low levels of parasitism and predation occur in various systems at different times during the production cycle. Studies must be conducted in order to elucidate the factors limiting the effectiveness of these natural enemies during these times. Estimates of percent parasitism (ratio of parasite adults to total SPW adults reared) may vary seasonally and over life stages. Parasite complexes may also vary among the different whitefly host plants although this has not been studied extensively. Most natural-enemy records have been obtained from surveys of cotton however, new natural enemy or host records are being obtained as we study whitefly populations on other cultivated and weed hosts.

Many species of SPW parasites are undescribed, and specimens of described species often can be determined only tentatively. The taxonomy of SPW

parasites will have to be greatly improved if a national biological control program is to proceed efficiently.

Although many fungi have been found in association with *Bemisia*, only *Verticillium lecanii*, *Paecilomyces fumosoroseus*, *Paecilomyces farinosus*, *Aschersonia aleyrodis*, and *Beauveria bassiana* have been demonstrated to be pathogenic.

Parasites and Predators. As most workers in this field are aware, many whitefly parasites belong to taxonomically unsettled groups. Specific identifications for species in the genera *Encarsia* and *Eretmocerus* are very difficult to obtain and often disputed by specialists .

Taxonomists urgently need financial support in order to provide the needed services required for progress in research on parasites that attack *B. tabaci*. Additional funding is needed for surveys of the parasite fauna in many areas of the world, pre and post introductory evaluations, and for continued maintenance of parasite cultures that show promise.

Encarsia formosa is the only species commercially available at this time. Reports on its ability to reduce *B. tabaci* populations have been mixed. There are many possible reasons for this; most probably relate to *Bemisia's* occurrence over a wide range of host plants, cropping and environmental conditions. Studies are currently being conducted to compare this species with others commonly found attacking *B. tabaci*. It has been suggested that *Encarsia formosa* may provide acceptable control only under conditions where SPW is limited by sub-optimal temperatures such as occur at the northern limits of its distribution in the field and in northern glasshouse culture or on plants which are marginally suitable for the development of whitefly populations.

Whiteflies, parasites (*Eretmocerus* spp. and *Encarsia* spp.) and predators can be found in Florida, Texas, and southern California throughout the year on wild lettuce, *Lactuca serriola* L. and wild sunflower, *Helianthus annuus* L. and many other crop and wild hosts. In the Imperial valley seasonal trends of parasite populations were similar for both genera but *Eretmocerus* parasitism was always greater than that of *Encarsia*.

Field surveys in Florida for natural enemies of the sweet potato whitefly have identified at least 11 parasite species. Of these, *Eretmocerus californicus*, *Encarsia deserti*, *Encarsia nigricephala*, and *Encarsia tabacivora* are the most abundant and widely distributed. The impact of natural enemies on whitefly populations in unmanaged habitats appears to be substantial and increasing with time. It is usually difficult to find large whitefly populations in such areas, and parasitism and predation are often high. A two year survey in the Caribbean Basin has identified at least 15 species of parasitic Hymenoptera attacking *B. tabaci*, with *Encarsia tabacivora*, *E. nigricephala* and *Eretmocerous californicus* predominating.

Results in most whitefly infested crops suggest that parasite populations do not exert a significant impact on early season SPW populations. The parasites were dependent on host density for population establishment and increase.

Parasitization and predation in weeds have been heavy, at times reaching >90%; however, fewer natural enemies have been observed in commercial tomatoes presumably due to the large insecticidal inputs. Means of encouraging parasite and predator movement into fields in conjunction with reduced commercial use of insecticides are needed.

Considerations of host finding efficiency and of rearing expense are very important in evaluating candidate biological control agents. *Eretmocerus* species appear to be more efficient in host finding and possess a desirable functional response; and being arrhenotokous unlike most *Encarsia* species, may be easier and cheaper to rear. Some species have longer developmental periods from oviposition, but this may be offset·by higher searching and oviposition rates.

Currently, there are over 7 different colonies of parasites being maintained in the Florida Department Agriculture and Consumer Services quarantine facilites. Some of these cultures have been cleared for further evaluation and eventual field releases but funding has not been available for scientists in Florida or other states to conduct the research needed prior to any release.

There are many predators that will attack whiteflies. These include various Hemiptera (especially Anthocoridae, and predatory Miridae), Coleoptera (Coccinellidae), Neuroptera (Chrysopidae, Hemerobiidae, Coniopterygidae), Diptera (Dolichopodidae, Syrphidae, Anthomyiidae), Hymenoptera (Formicidae), Araneida and Acarina (Phytoseiidae, Stigmaeidae). Some of these are opportunistic predators of adult whitefly, others are general predators of leaf-feeding Homoptera, still others are specific predators of whiteflies. Very little information is available on the biology and impact of most predators of sweet potato whitefly, especially in field crops. In a preliminary survey of predator species attacking *Bemisia* on unsprayed tomato, at least 11 species were identified including *Delphastus pusillus* and *Chrysoperla rufilabris*.

The most promising predator to date for use in greenhouses is the coccinellid, *Delphastus pusillus* Casey. This species is distributed across most of the southern and eastern U. S. and throughout the Caribbean, Central and northeastern South America. Larval and adult beetles feed voraciously on eggs, immatures, and adult whiteflies. They feed specifically upon whiteflies, but will accept broad mite eggs and spider mites as alternate prey if whiteflies are not available.

Another coccinellid, *Clitostethus arcuatus* (Rossi), has been implicated in dramatic reductions of whiteflies in small research greenhouses in Israel but biological data are sparse. This species appeared on its own inside two greenhouses containing cotton plants and lantana. *C. arcuatus* was first detected in mid June. By the 3rd week of July both greenhouses were completely clean

of SPW and stayed clean until mid August. The beetles then disappeared and did not reappear when SPW reappeared in September. This species was recently imported into California for evaluation against the recently introduced ash whitefly, *Siphoninus phillyreae* (Halliday).

Chrysoperla carnea (Stephens) larvae of all stages voraciously attack the various whitefly stages on the cotton leaves under laboratory conditions. When ten 1st-stage lacewing larvae were placed on each of 3 leaves on a cotton plant having either 3-4 or 6 leaves, there was a significant reduction in the number of adult whiteflies present on the leaves 2 days later. This reduction continued for at least 5 days, even though the lacewing larvae had died or moved off the cotton leaves 2 days after placement on them. Reduced adult whitefly visitations and oviposition activity on the plants in the presence of lacewing larvae resulted in significantly fewer 1st stage whitefly larvae present 6 days after the lacewing larvae had been placed on the plants. Similar results were obtained when *Chrysoperla rufilabris* larvae were released into a caged greenhouse situation for control of SPW on ornamentals. Depending upon the number and configuration of the plants involved in the release area, differing numbers (8-50) of larvae were able to significantly reduce SPW numbers to non-economic levels allowing commercially viable plants to be produced without insecticide application.

Artificial honeydews can increase fecundity of *Chrysoperla carnea* and result in greater predation in the field. Tryptophan was found to be highly attractive to *C. carnea* in the field and laboratory. Various breakdown products, particularly indole acetaldehyde, were also attractive in the laboratory. The effects of artificial honeydews and attractants on parasites and other predators attacking *Bemisia* have not been investigated.

A coniopterygid obtained from Kenya was released in Israel but disappeared after one generation in the field before significant data were obtained. Substantial mortality due to predation by coniopterygids has been observed on whitefly in California in some tree crops.

Geocoris punctipes has also been demonstrated to be predacious on SPW adults. SPW were nutritionally adequate for sustained support of the predator.

Polyclonal antibodies have been developed for field testing of SPW predation. Extensive screening for cross-reactions are planned to rule out false-positives.

Laboratory cultures have been established and maintained for several species of parasites and predators of *Bemisia*. Material from these cultures has been supplied to numerous state and federal researchers and commercial insectaries. Laboratory studies have been conducted on the developmental biology, feeding behavior, oviposition, and searching behavior of several indigenous natural enemies of the sweet potato whitefly (*Delphastus pusillus, Encarsia transvena*, and *Eretmocerus californicus*).

Fungal Pathogens. The use of insect pathogens for the control of whiteflies dates back to the early part of this century when Florida citrus growers used *Aschersonia*. This fungus was encouraged to grow on whiteflies infesting citrus trees. Branches were then harvested from these trees and the infected whiteflies moved throughout the state to facilitate the spread and control of citrus whiteflies by *Aschersonia*. Problems with the control of greenhouse whitefly in greenhouses resulted in the development of a commercial products which contain strains of the fungus *Verticillium* (*Cephalosporium*) *lecanii*.

Studies have been conducted to determine the potential for using *Paecilomyces fumosoroseus* and *Beauveria bassiana* to control *Bemisia tabaci*. Both pathogens have been responsible for reducing populations of whiteflies under specific conditions. *Paecilomyces fumosoroseus* and *Beauveria bassiana* possess many desirable attributes; tolerance to pesticides, ease of production, and a broad spectrum of activity. Commercialization of both pathogens is currently being pursued in the USA.

Conservation of Natural Enemy Populations. Many species of whitefly parasites and predators will attack other species of whitefly when they are sympatric with *Bemisia*. Research is needed to determine the importance of wild populations of whitefly as natural enemy reservoirs in the vicinity of field crops and the influence of weedy and native plant hosts on the movement of whiteflies and natural enemies into adjacent areas. Existing opinions on the size and importance of wild populations of *Bemisia* are somewhat contradictory. Whitefly species in general do not reach damaging levels in undisrupted habitats, an indication of the impact of their natural enemies and of environmental mortality factors. Further improvements in the specificity of new pesticides such as growth regulators are likely to create new opportunities for conservation of natural enemies.

Intercropping can be an alternative method for the reduction of pests in certain situations. Beneficial insects are often increased and their activity enhanced on intercrops. Recently, intercroppings of tomatoes have been shown to be beneficial. Various intercropping systems have been shown to contribute to the reduction of whitefly populations. Cucumber planted in alternating rows 30 days before tomato delayed infection of the tomato with the whitefly-vectored tomato yellow leaf curl virus.

Although adult *B. tabaci* are attracted to yellow, the incidence of tomato yellow leaf curl virus was delayed 20 days on tomato plants grown on yellow polyethylene film. Spraying the yellow plastic with vegetable oil resulted in even less *B. tabaci*-vectored geminivirus in Florida. Furthermore, orange or UV-reflective aluminum painted mulches also delayed the virus.

Opportunities for Integration with Chemical Pesticides. Integration of natural enemy releases with existing pesticides used against *B. tabaci* will continue to be an important goal. Many currently registered pesticides are very detrimental to natural enemies. Insecticidal soaps and oils, and pesticides containing neem are

a few compounds that allow some parasite and predator activity. Results of tests with predators and of cotton aphid and sweet potato whitefly show that neem extracts were relatively non-toxic and did not greatly reduce predation and parasitism. Parasitism by *Eretmocerus* sp. and *Encarsia transvena* was recorded in several greenhouse trials in which Margosan-O was applied up to four times. In each case, plants treated with Margosan-O had levels of parasitism comparable to unsprayed controls or significantly higher than when other pesticides were used.

Development of new growth regulators for whitefly control such as buprofezin and those compounds that belong to the benzoyl urea group (teflubenzuron, CGA-184699, andalin) offer additional hope for the future compatibility of selective insecticides with natural enemies. These materials have significant activity against specific whitefly stages: eggs and early instars. Since parasites will attack older nymphs and prepupae, we may be able to integrate the two approaches. Selective compounds could be used to reduce the whitefly populations to levels where parasites could be more effective and keep this pest in check.

Initial results with potentially selective compounds from trials in Florida demonstrated that parasites persisted in trials using kinoprene, CGA-184699, teflubenzuron and fenoxycarb. Some IGRs (buprofezin) were so effective against SPW that no nymphs remained for parasites to attack, so their immediate effect on the parasites could not be assessed.

Buprofezin was evaluated under field conditions in Israel for two years. The effect of this compound on individual species varied: *Eretmocerus mundus* was negatively affected, perhaps because it selects younger whitefly nymphs to parasitize than *Encarsia* species, and parasitism due to it alone declined slightly in IGR treated plots. Parasitism by *Encarsia lutea* increased slightly in the treated plots.

By combining an effective IPM scouting program with judicious selection of biological, cultural and selective chemical controls, we are hopeful that this whitefly can be managed effectively using the variety of available agents.

3. **Significance**

Classical and augmentative biological control approaches have considerable merit and, in view of the increasing economic importance of the SPW, should be a principal focus of attention. Particular attention should be given to quantifying natural enemy impact, defining their role in SPW integrated management programs, and explaining their apparent lack of effectiveness under some crop production systems. Pathogens of SPW have demonstrated considerable potential. Two species, *Beauveria bassiana* and *Paecilomyces fumosoroseus* are in early stages of commercial development in the United States.

Control of *Bemisia tabaci* can be improved by curbing its population growth during three phases: a) the overwintering, wild-host phase; b) the low population, "acclimatization" phase; and c) the outbreak phase.

a. Increasing rates of parasitism at the overwintering and wild-host phase will reduce the migrant population. The reduction of *B. tabaci* migration to the target crops will result in lower initial infestations and fewer reproducing whitefly during the "acclimatization" periods.

b. The initiation of the "acclimatization" phase occurs during the onset of warmer temperatures, which are suitable for both pest and parasite activity. Further reduction of the *B. tabaci* population by natural enemies during this phase may well prevent or delay a damaging whitefly population explosion during the outbreak phase.

c. Different species of hymenopterans are known to employ different searching, host selection and reproduction strategies. It is expected that the successful introduction of new and more effective natural enemy species and biotypes will provide better population regulation of *B. tabaci* during a reduced or delayed population outbreak phase, because of improved ability to increase proportionately with the whitefly population.

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TABLE D. Biological Control

Research Approaches	Year 1	Year 2	Year 3	Year 4	Year 5
D.1 Determine effects of indigenous natural enemies on regulating SPW populations.	Survey for and identify key natural enemies in various habitats and seasons.	Continue survey; culture and study reproductive biology of beneficial species.	Continue biological studies; determine effectiveness of species under various habitat and weather conditions.	Determine interactions among SPW, host plants and natural enemies.	Examine species and methods for exploiting selected natural enemies in crop systems.
D.2 Develop methods for enhancing habitats with refuge plantings to conserve natural enemies.	Establish refuge plantings; colonize parasitoids; sample for and identify native natural enemies.	Continue sampling; test inoculative parasitoid releases; determine SPW/parasitoid interactions.	Evaluate refuge plantings as field insectaries on larger scale.	Continue evaluation of most promising methods.	Implement and evaluate large scale conservation management systems.
D.3 Identify new natural enemies in areas of SPW origin; foreign exploration, importation and release.	Collect, identify and import exotic natural enemies from specific habitats.	Continue collections; assess biology and host relations; develop rearing techniques.	Continue collections; determine habitat "fit" for each candidate; assess interactions with native species.	Conduct host range tests; rear, release promising natural enemies.	Determine adaptation of introductions and effects on SPW populations.
D.4 Determine natural enemy host selection processes and mechanisms.	Study mechanisms involved in natural enemy host foraging.	Study efficiency of host foraging mechanisms.	Determine factors affecting interactions of host foraging mechanisms, hosts and host plants.	Determine potential of implementing host foraging mechanisms in SPW population management.	Implement methodology developed into SPW management systems.
D.5 Inoculate/augment parasite and predator populations through propagation and release.	Identify best candidates for augmentation based on selected attributes.	Develop laboratory rearing procedures for select species.	Conduct tests on technical feasibility of inoculating/augmenting predator/parasite populations for suppression of SPW.	Develop mass propagation and release procedures for selected species.	Conduct areawide suppression trials and continue developing the mass propagation, distribution, storage and release technology.

D.6 Determine effects of pathogens on regulating SPW populations.	Determine role in specific crops; develop culturing techniques.	Screen candidates for efficacy and effects on non-target organisms.	Evaluate for efficacy and persistence in small plots; develop formulations, evaluate for micotoxins.	Monitor dispersal and begin large scale field evaluations. Evaluate persistence and develop protocols for suppression of SPW populations.	Expand field evaluations and begin technology transfer.
D.7 Evaluate compatibility of pesticides with SPW natural enemies.	Laboratory screening for effect of pesticides on selected SPW natural enemies and develop baseline data.	Survey for geographic variation to pesticide exposure and select natural enemies with pesticide tolerance; identify pesticides that are compatible with natural enemies.	Challenge selected natural enemies to develop resistant strains.	Limited field trials to determine effectiveness and survival of resistant natural enemy strains.	Evaluate potential in large scale field trials.
D.8 Systematics of predators, parasites and pathogens.	Finalize taxonomist network; inventory species, literature, collections; survey NA fauna and flora; establish common curation techniques.	Continue survey; identify and voucher exotic material; implement protocols.	Review critical genera; establish limits of relevant species worldwide.	Describe new taxa, prepare keys, characterize phylogenetic relationships.	Conduct molecular, biochemical, or other studies on target taxa.

E. Crop Management Systems and Host Plant Resistance

1. Introduction

Growing sequences of cultivated crops and the ready availability of alternate hosts in southern agro-ecosystems provide continuous sources of host material for sweetpotato whitefly (SPW), *Bemisia tabaci* (G.), reproduction throughout the year. SPW populations typically increase more rapidly under warm climatic conditions and are therefore more problematic during the late spring, summer and early fall. However, over-wintering SPW populations can be a source of early-season infestation. High initial SPW infestations, lack of natural or insecticidal controls, and climatic conditions may determine the severity of SPW infestations during the growing season. Planting, harvest, and post-harvest windows may be used for specific growing areas to establish host-free periods to eliminate or reduce the number of SPW, associated viruses, and physiological disorders. Major factors contributing to SPW migration in the southern states include the lack of field sanitation, neglecting to destroy crop residues, volunteer crop and weed hosts, and defoliating the crop without concurrent SPW control. Non-cultivated hosts in areas peripheral to crop production fields can be refugia for SPW and associated natural enemies.

Host plant resistance has potential as an integrated pest management component for suppression of SPW populations and may provide a more bio-rational approach for reducing the impact of SPW transmitted viruses and plant disorders than reliance on pesticides. Plant breeding efforts currently being made in this area of research are too few to be effective in commercial production systems. However, numerous preliminary studies in cotton and vegetable crops suggest a wide range of intra- and inter-specific host susceptibility to SPW and associated plant viruses.

2. Research Accomplishments

Few experimental trials have been reported that attempt to exploit crop sequences, proximity of susceptible crops, or cultural controls as a strategy for delaying development of early SPW infestations that lead to the development of high SPW populations later in the season or in subsequent crops. In the Imperial Valley of California, short season cotton production and early termination reduce honeydew accumulation on lint. Also, the early defoliation reduced SPW migration to vegetable crops and resulted in lower incidence of lettuce infectious yellows. In the Lower Rio Grande Valley of Texas in 1991, delayed fall plantings of cucumber resulted in a dramatic decrease in SPW damage compared with an earlier planting of cucumber during the heaviest SPW migration from cotton. In Florida UV-reflective, orange, and yellow mulches have been shown to delay the buildup of SPW and infection of SPW transmitted tomato mottle gemini virus in tomatoes. Floating row covers have been used for excluding viruliferous SPW and aphids from susceptible host crops. Removal of covers at the time of pollination during low SPW pressure can result in superior fruit set. Overhead irrigation has been reported as a means of reducing SPW

adult numbers in the field and may aid in the use of SPW entomopathogens by modifying ambient relative humidity for improved infection of SPW nymphs. Other cultural practices have been used to control SPW borne viruses, including windbreaks, intercropping, higher density plantings, but those that have been reported as most successful have been the timely removal of the crop at the end of the season (including burning of residues), the removal of volunteer host plants, and some type of spatial or temporal separation of sequential host crops (possibly using upwind planting as an aid to spatial separation).

Several studies on host preference and SPW development indicate that there is considerable variation within crop plant species in their ability to attract SPW for oviposition and feeding or support nymphal development. Coudriet et al. reported an average of 9 d shorter SPW development time and ten-fold greater adult emergence on cucumber than on broccoli under controlled conditions. However, Coudriet's test was not a choice test and it has been shown that SPW can choose a host that is not the most appropriate host. Recent evaluations of SPW host plants as trap crops in Florida indicate SPW adult preference as follows: squash > eggplant > tomato > okra. In other host preference evaluations the number of SPW adults was significantly greater on squash and cotton than on lettuce and carrots after 3 d exposure in the greenhouse. Correspondingly, the highest number of eggs were found on squash, followed by cotton, lettuce and carrots.

Resistance to SPW in wild tomato species and cultivated x wild hybrids was associated with the density of sticky, glandular trichomes. Germplasm resistant to various viruses, including tomato mosaic gemini virus has been identified. *L. chilense* has demonstrated high levels of resistance to tomato mottle gemini-virus and appears to be governed by two inheritance mechanisms. Embryo rescue techniques have been used to improve the crossability with *L. esculentum*. Resistance to leaf silvering symptoms in squash has recently been identified, but the mechanisms of resistance have not yet been determined. Large variation in SPW ovipositional preference, nymphal development and susceptibility to SPW-transmitted Texas pepper gemini virus has been observed between pepper types and elite pepper breeding lines in replicated field plots. The essential amino acids for SPW have been identified, which could lead to screening for germplasm for abundance of specific amino acids as a source of resistance to SPW.

Glabrous leaved cottons in a number of genetic backgrounds support lower populations of SPW than do hairy-leaf cottons. Resistance to SPW in okra-leaf cotton has been reported, but data are equivocal. Resistance to cotton leaf crumple virus (CLCV) in the cotton variety 'Cedix' from El Salvador was found to be partially dominant to CLCV susceptibility in 'Deltapine 90', a SPW tolerant cultivar. There have been persistent reports of SPW resistance in the Desi cottons (*Gossypium arboreum*) and in the wild *G. lanceolatum*. The results of nine separate experiments involving 8 to 16 plant entries per experiment show considerable variation within different cottons with known nectariless, okra-leaf,

pubescent, red plant color, and other characters suggesting a broad base of genetic germplasm as sources of SPW resistance.

Existing evidence shows a wide range of variation of SPW susceptibility within and between various crops. The information suggests a broad range of existing germplasm for selection of resistant plant types. Because of difficulties in attaining adequate insecticidal control of viruliferous SPW, host plant resistance may play a major role in the management of SPW transmitted viruses and other SPW induced plant disorders. Different strains of SPW recently identified exhibit different behavior patterns which may impact upon the plant/SPW relationship, particularly in the areas of virus transmission, feeding damage potential, host adaptability and host range.

3. **Significance**

The impact of new strains of SPW on host plant resistance mechanisms needs to be considered in all future SPW host plant resistance and integrated crop management studies. Because of the seriousness of the SPW problem, including direct effects as well as effects of associated viruses and physiological disorders, a short-term solution is urgently needed. Therefore, research on various cultural methods should be continued and expanded. Three broad areas of research on cultural methods, which have shown promise with various crops and at certain locations, are: 1) manipulation of crop production inputs, such as irrigation, fertilization, crop termination, and plow-down; 2) determination of the effects of various temporal and spatial cropping arrangements, such as delaying the planting of a vegetable crop following cotton to reduce SPW and viruses, or planting the later crop upwind from the earlier crop; 3) the use of innovative practices, such as the use of colored mulches, row covers, and trap crops.

Long term solutions to the SPW problem are also needed. Certain cultural practices, such as host free-periods, could provide long term solutions, but this remains to be seen. The discovery and utilization of natural resistance of the plant to the insect, viruses, and physiological disorders (host-plant resistance) are worthy goals that deserve research attention. This research will require close cooperation among plant breeders, entomologists, virologists, plant physiologists, and other scientists. Three broad areas of research in host-plant resistance are as follows: 1) development of reproducible methods to evaluate germplasm for resistance; 2) the discovery and identification of resistant germplasm; 3) the utilization of resistant germplasm in improved cultivars. These three areas will not be researched separately and in isolation, but together and interdependently.

Breeding goals will differ considerably, depending upon the crop involved. For example, in cotton in the United States, development of a modest level of resistance to SPW will be sufficient because plants can tolerate moderate populations of the insect without economic consequence, and the CLC virus is not usually a serious problem. In vegetable crops, on the other hand, important goals will be to utilize resistance both to SPW and to viruses, because both

inflict economic loss. In certain ornamental crops, a very high level of resistance will be sought, because retailers and consumers expect clean plants. Recent favorable results with transgenic crop plants that carry insect-resistant and virus-resistant genes from other organisms should encourage research in this area to combat the SPW and associated problems.

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TABLE E. Crop Management Systems and Host Plant Resistance

Research Approaches	Year 1	Year 2	Year 3	Year 4	Year 5
E.1 Determine effect of traditional crop production inputs on SPW population development.	Investigate effects of irrigation, fertilization, and plant growth characteristics on SPW population dynamics.	Identify crop production methodology that may be a factor in SPW population development.	Determine mechanisms involved in crop production factors which greatly affect SPW biology, behavior, etc.	Determine possibility of exploiting or manipulating crop production methods as a factor in SPW management.	Develop methods that are grower acceptable to minimize SPW damage and maximize profits.
E.2 Determine temporal and spatial effects of host plants on SPW populations and dispersion.	Determine SPW reproduction, population development and factors affecting them on selected major crops and weeds.	Identify preferred cultivated and weed hosts and contribution to overall population density and SPW dispersion.	Determine interactions of cultivated host sequences and weeds on SPW population development and movement.	Determine potential of manipulating cultivated host sequences during growing season to reduce SPW populations.	Develop best strategy for cultivated host sequences that will minimize SPW damage to crops.
E.3 Determine effect of colored mulches, trap crops, intercropping, row covers, and other innovative cultural practices as potential SPW control methods.	Identify cultural practices in crop production systems affecting SPW biology and behavior.	Determine potential effectiveness of innovative cultural practices on SPW behavior.	Conduct studies to determine potential of cultural practices to affect SPW population development in the field and affect yield.	Identify cultural factors with greatest potential for adversely affecting SPW population development and improve yield.	Incorporate best potential factors into system and determine effect on SPW and crop net returns.
E.4 Develop reproducible evaluation techniques to isolate resistant germplasm.	Determine rapid, reproducible evaluation techniques for identifying resistance germplasms.	Apply developed methodology to identify resistant germplasm.	Use improved evaluation techniques to identify resistance mechanisms.	Begin to characterize resistance mechanisms and to identify chemical/morphological components.	Continue characterization of resistance mechanisms.

E.5 Identify resistant germplasm to SPW and associated viruses and plant disorders.	Collect potential sources of resistance germplasm.	Screen and identify resistance sources.	Quantify effects of resistance characters on SPW, virus, and associated plant disorders.	Determine interaction of selected plant types and SPW populations in the field.	Continue evaluation of selected plant types for management of SPW.
E.6 Conduct plant breeding studies to select SPW resistant plant germplasm.	Conduct plant breeding studies to incorporate resistance into acceptable plant types.	Continue plant breeding experiments to produce highest resistance levels.	Begin to transfer resistance factors into improved plant types.	Continue the transfer program.	Continue the transfer program.

F. Integrated Techniques, Approaches and Philosophies

1. Introduction

In this 5-year national plan for development of management strategies for the SPW, several basic assumptions must be made about relative importance of pursuing various avenues of research activity. In an effort to identify gaps in our knowledge and take advantage of existing research and implementation projects we have constructed a "total project" plan in the previous 5 sections of this document. They include most areas of interest and concern identified through years of experience dealing with pest problems. Research addressing these areas typically utilizes reductionist approaches, where researchers will apply their specific disciplinary skills to narrowly-defined components of the overall SPW problem. The assumptions made by designing research efforts in this way fall into two categories; 1) that a "silver bullet" will be discovered that by itself will resolve the problem (a powerful resistant variety, a formidable parasite, or a super pesticide, etc.), or 2) that the research information generated will automagically (automatically) converge on some holistic framework allowing research to nicely fit together into an effective management strategy. Historically, neither scenario has worked for sustained periods. It is, therefore, important that researchable areas which specifically integrate (synthesize) rather than fragment (reduce) be an explicit research and implementation component of the 5-year plan.

2. Research and Implementation Areas

Based on extensive discussion at the SPW workshop held in Houston (February 1992) many integrating techniques, approaches and philosophies were identified and evaluated. Many of these areas hold potential to deliver substantial benefits to the overall project if explored in parallel with other project areas. From the examples identified, five major categories of integration were formulated and listed as Research Approaches in the 5-year plan (see table F). These approaches are Risk Assessment, Ecosystem Modeling, Networking, Spatial Analysis, and Interactive Extension Delivery Systems. They each represent major research and implementation activities individually while simultaneously serving to integrate information, ideas and action across disciplines and other lines of demarcation.

a. Risk Assessment

Risk assessment involves both the direct and indirect effects which impact the production system. The direct effects are economic in nature and cause immediate monetary loss to both the produced and associated infrastructure that supports the production. The indirect effects are primarily non-economic and involve issues considering the quality of the environment and the acceptability of particular actions. At times and under extreme conditions, indirect effects may

also become economic in nature. Producers must integrate a great deal of information to properly assess their risk to the SPW. Financial institutions, insurance company, and commodity market analyses must also evaluate risks associated with rapidly changing production environments and control options. Producers not previously affected by SPW will also be impacted by relative risk assumptions made at other locations.

It is important to note that the SPW is not a major pest outside of greenhouses over much of its distribution. Control factors are unknown but the overall effect is to keep the SPW under natural control. Many such areas exist in the United States and need to be specifically cited for research activity since there are few or no local incentives to study a nationally important pest that locally is a non-pest. Disrupting these effective control systems before we understand their value is a very likely and common scenario. It is in these locations that information on how to manage SPW will most easily be found since the environmental factors that keep them under control are intact.

Making risk information available to producers in a timely fashion is the single most important activity for the management of this pest in both high and low density areas. How this assessment is made is critical and needs to have a high priority during the first year. It must integrate with all other aspects of the 5-year plan and become an integral part of the objectives for spatial analysis, ecosystem modeling and networks. Risk assessment and Integrated Extension Delivery programs will be the first line of defense against next year's crop losses caused by SPW.

b. Ecosystem Modeling

Ecosystem modeling has as its objective the systematic evaluation of alterative spatial and temporal designs of the entire landscape of a region not just a specific commodity or field. More specific modeling work will be done in other research areas but will not address similar regional characteristics of the SPW problem. The effective use of ecosystem modeling requires the assumption that control aspects for this pest will be found outside of the agricultural crops or by considering many crops simultaneously. This concept is central to Biological Control, Crop Management and Population Dynamics of the pest and its natural enemies. The basic components within such an ecosystem analysis will be a series of general models on crop phenology, SPW population dynamics, disease epidemiology and background information on natural enemies, weed phenology and pesticide impact on all components. The overall ecosystem model will be driven by temperature, day length and other relevant environmental parameters. Most information to develop and support this activity will be accumulated in other parts of the 5-year plan. The purpose for this integrated ecosystem approach will be to interface these components with prevailing wind flow, crop

sequencing and migration models for input to a Geographic Information System (GIS). The GIS will be used to display and analyze alterative spatial crop production systems or other management tactics implemented at a regional scale.

The principal objective of this model-to-GIS interface will be to develop an interactive system for displaying and exchanging biological data and projections on a large multi-crop spatial scale (over multiple crops and multiple years) for different geographical regions. The individual crop models can be relatively simple since we are not targeting high resolution on a single crop at a single location. In this type of analysis it is anticipated that timing and intensity of whitefly migration in relation to crop initiation, variety, and spatial location will be important components in studying, managing, and ultimately understanding the system. Therefore, an interactive link must be established early in this research between the spatial-temporal sequence of crops in different growing regions of all participating states with the temporal ecosystem models. The best mechanism for accomplishing this will be to establish a GIS information network between all participating regions. Many states and agricultural agencies are already collecting base map data on crops in their region, and some already have this information in GIS systems. What is needed is a fast network capability to process and transfer current biological information concerning SPW populations from one area to another. A central site will not be necessary if survey techniques are coordinated. By making location specific growth rates of crops available projections can be produced by applying migration-ecosystem models to the spatial map. Thus, the information can flow from region to region for analysis and predictions. Local participation is critical for accumulation of site specific biological data and for on-site use of analysis results. Particularly important are "initial conditions," i.e., whitefly abundance early in the season, parasite and predator densities, planting dates, crop and variety, etc. This establishes the starting point for projections and validation of previous predictions. Only in this way will be obtain feedback on the accuracy of projections to help with model development and improvement.

c. Networking

Recent developments in information dissemination technology have changed dramatically in the last 10 years. These effective and efficient advancements in telecommunication, CD-ROM memory technology and expert systems are all technically available for use in the SPW National Program. There use will help to connect and coordinate the many diverse components of the program. For example, the USDA-APHIS, NBCI has recently established a SPW bulletin board for use by cooperators to make data and information rapidly available to extensive groups of participants.

As research develops on the SPW over the next 5 years it will be possible to integrate all available information into an "Expert System" to take advantage of new information and continue to use information already available. This activity will cut across all research areas and make data available to the Interactive Extension Delivery System (IEDS for SPW).

Expert systems are computer programs that attempt to model a decision-making process to arrive at solutions to complex problems. They were originally developed as part of artificial intelligence research, but are now used to capture information and organize it in a sequential hierarchy to help solve everyday problems by interacting with the end user. Expert systems make inferences and conclusions from information supplied by the user and are commercially sold for design engineering, financial analysis and data inquiries. These software products use background facts, rules and assumptions as experts would and in many systems, attempt to simulate the human decision process. Many such systems are now used by farmers, IPM and Cooperative Extension specialists involved in pest management. An expert system called HOPPER, developed by the USDA-ARS, is now being used to manage grasshoppers on a spatial scale similar to those needed for SPW.

d. Spatial Analysis of SPW Populations

When dealing with pest problems we often define populations as densities within a single field or group of fields of a single commodity. We will not be able to address the SPW in this manner since it infests many different crops and becomes a problem over a definable region. Most population studies choose to deal with the abstraction of a population as if it exists at a single point in space without individual variation or with variation expressed as a statistical mean. Both of these assumptions are false but usually of little consequence in a large monoculture with a homogeneous pest population. This appears not to be the case of the SPW. The use of the word region here refers to a contiguous area of several square miles which contain all of the components of the problem, such as all crops, inter-field environments, overwintering habitats, disease incidence and inoculum sources. Geostatistics is used to analyze the spatial relationships of the components. The Geographic Information System (GIS) can be used to map and orient data on a two-dimensional plane as overlays, visually present multiple overlays simultaneously and assist in spatial analysis of diverse components.

Risk assessment objectives will need to interface with the ecosystem models and the spatial matrix of crops in several important ways. The general spatial-temporal design of the agricultural landscape can be studied by simulation using the spatial-temporal models. Different crops and spatial patterns can be tested and infestation levels of whitefly predicted for developing "minimum risk" strategies. "Background" populations of whitefly in relationship to natural

enemies overwintering on weeds, crops and native plants, can be included in the analysis. This will allow the simulation of several contiguous years to evaluate long-term risk of a particular year's policies. We can study this system spatially in the presence and absence of plant virus and partition economic losses to causal agent for crop loss assessment.

Pesticide application information will provide an additional link to the GIS database and be an essential assessment required for biological control implementation. This interface will also apply to the risk assessment section and will be important for both economic and environmental impact analysis, particularly environmental quality and impact on regional populations of natural enemies.

Regional economic analysis will be effectively supported by GIS analysis; for example, maximize the total dollars/ha for the area vs. producing a "stable" system or optimize the return to a particular crop or to take a particular crop out by reducing the density of another crop. Linking the ecosystem models, GIS and the Extension Delivery component will be one of the basic tools of the risk assessment objective, and hence vital to our overall effort.

e. Integrated Extension Delivery System

The education of producers, private consultants, associated agricultural specialists and homeowners is a key component to an effective management solution to the SPW problem. Because of the broad host range, intra- and inter-crop movement, and long-range dispersal of SPW, it is necessary that community-wide action programs be developed for the management of this pest. Marketing associations, Co-op's and Task Forces could provide core membership and organizational support. Efforts should be made to include homeowners in these groups. Home gardens and ornamental plantings may be reservoirs for SPW and they can also be severely damaged. Representatives from these community groups should be included in the planning process for research and extension/education efforts both locally and nationally. The Cooperative Extension System can organize and support these groups with community education programs, but other USDA agencies involved with crop production, protection and marketing should also be involved. Increased research effort is required to develop long-term solutions to the SPW problem, but the current severity of the problem requires the immediate initiation of educational programs. The following management strategies need to be reviewed and evaluated for their role in suppressing SPW populations. Each has its individual impact on the severity of the problem, but their aggregate impact is not known. At present, they appear to be the bases for initiation of an education program with information currently available on issues around which community action can be developed. These strategies were presented at the Inter-agency

Workshop for the Development of Management and Control Methodologies for the Sweetpotato Whitefly, *Bemisia tabaci*, held in Houston, Texas on February 19-21, 1992. These general recommendations regarding educational program content for the management of the SPW are a summary of comments provided by the Extension IPM Coordinators from Arizona, California, Florida, Georgia, Hawaii, Maryland, Massachusetts, and New Mexico.

(1) Reduction of pesticide used and resistance management: Insecticides are not the answer to the sweetpotato whitefly problem. Insecticide applications are particularly ineffective when SPW populations are rapidly increasing (e.g., late summer and early fall), are very large (e.g., 3000 eggs/in.), and/or can readily reinfest a crop by moving to adjacent fields. There is evidence that, if insecticides are applied, the development of resistance may be slowed when insecticides are applied in combinations and products with different modes of action are used in rotation. However, the impact of these strategies on natural enemies must be evaluated.

(2) Long host-free period: This is probably the most effective management option, but also one of the most expensive. Grower incentives that encourage the adoption of host-free periods may be needed.

(3) Crop sequencing: Crop sequencing patterns can be effectively used to restrict host availability during certain periods. Crops that are planted early in the season may avoid large late-season populations of sweetpotato whitefly. For example, infestations of vegetables may be reduced by planting short-season cotton and delaying the planting of fall vegetables. Appropriate sequences must be evaluated for economic viability. The long-term success of this strategy will require area-wide coordination among producers.

(4) Timely crop and weed destruction: Crop refuse should be destroyed immediately after harvest and volunteer plants and weeds should be destroyed between crops. Herbicides, herbicide-insecticide combinations, burning of crop residue and deep discing may be effective management techniques that will require evaluation and demonstration trials. However, it will be important to evaluate the impact of these strategies on natural enemy survival if an effective IPM program is to be developed.

(5) Other cultural controls: Cultural controls alone cannot effectively suppress SPW, but they can delay population growth and increase the effectiveness of other management techniques. A few cultural controls that may be effective components of a management strategy are a) maintenance of an optimum nutrient balance, b) not planting near an infested crop of a weed

reservoir of non-parasitized SPW population, c) use of "clean" transplants, d) field preparation at least one month prior to planting, and e) the use of resistant varieties once they are available.

(6) Field monitoring/scouting: This is essential for early detection and subsequent population monitoring of SPW. Predator and parasite populations must be monitored to determine pest management options.

(7) Careful greenhouse management: Greenhouses may serve as reservoirs of sweetpotato whitefly that disperse into fields directly or via transplants (e.g., tomato). This source of sweetpotato whitefly may have a tremendous impact on the development of insecticide resistant populations. Greenhouse IPM programs are recommended and should include a) periodic monitoring of pest populations, b) use of trap plants, c) targeting problem areas (e.g., around vents and steam pipes) with management efforts, d) careful use of insecticides, e) a host-free period to break the life cycle and f) field strains of SPW populations may also disperse into the greenhouse and require new or different control procedures. Careful monitoring of greenhouse populations needs to be a major component of the national program. The entire North American greenhouse industry may be severely impacted by the development of new field strains in southern regions and then redistributed to more northern regions outside of SPW field distribution.

(8) Trap crops Since SPW may prefer cucurbits and eggplants for oviposition, the use of these plants as trap crops may be an effective strategy for tomato, okra and bean production. Trap crops could also contribute to the build-up and dispersal of natural enemies. This approach may be effective in greenhouses when other controls have failed.

(9) Soil mulches: Yellow, orange, or UV reflecting soil mulches may delay infestation by SPW. Effective management strategies may combine the use of a trap crop with an appropriate soil mulch.

The above list is by no means comprehensive, but it does suggest a few management strategies that may contribute to SPW suppression until new management techniques are developed. The effort to manage SPW will require coordination and cooperation among researchers, extension staff, producers, the agro-chemical industry and homeowners at the local, regional and national levels. national workshops concerning the sweetpotato whitefly should strive to include representatives from each of these groups. As new management strategies are developed, community action groups will be the critical component of education programs. It would be wise to start forming these groups now.

3. **Cooperators/Co-investigators**

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N. Toscano	UC, Riverside, CA

TABLE F. Integrating Techniques, Approaches and Philosophies.

Research Approaches	Year 1	Year 2	Year 3	Year 4	Year 5
F.1 Risk Assessment.	Identify a National evaluation panel to characterize risk assessment information needed for producers and the environment. Design risk assessment procedures for whitefly virus.	Interface with objectives for spatial analysis, network activity, ecosystem models and design risk assessment procedures for whitefly.	Operate risk assessment system. Validate risk assessment estimates. Expand to other pests. Collate multi-location results. Interface with IPM programs and crop loss assessment.	Technology transfer to existing institutional responsibility.	Support risk assessment system and develop management procedures.
F.2 Spatial Analysis and GIS.	Establish a national center to coordinate a national network of spatial analysis with GIS capabilities. Determine information needs for SPW.	Establish a network of user-information coupling participants. Input of spatial data. Look at other pest problems.	Run and validate system performance. Interface system with ecosystem modeling activity. Interface system with existing IPM networks.	Transfer technology to existing institutional programs. Combine GIS data bases.	Operate system under new framework of administration. Troubleshoot activities.
F.3 Ecosystem modeling.	Establish a National ecosystem model panel to identify scale and attributes of components. Interface with network.	Develop site-specific models in all participating states site-specific models. Define appropriate resolution of modeling activity. Address other pest problems.	Interface with spatial analysis. Couple crop model with spatial data.	Use model with spatial analysis capability.	Transfer activity to state institutions and assist in specific activity.

F.4 Networks.	Test and run NBCI bulletin board. Expand network to international dimension for biological control information exhibition. Expand written materials and workshop presentations. Bring GIS up on networks.	Teleconferences on SPW nationally. Expand to agricultural ecosystem management. Coordinate GIS with networks.	Teleconference SPW program internationally. Begin transfer of GIS to extension applications.	Continue to operate system. Continue transfer of GIS to extension.	Transfer national activities to permінent institution support.
F.5 Integrated Extension Programs.	Identify existing task-force or action groups and link them into a communication network; written, electronic, radio and conferences. Support and expand information network, newsletters, news articles, video conferences. Interface with appropriate National and State crop programs.	Develop procedures for data capture at local sites throughout the country and expand to other sig-nificant pests. Access spatial data and eco-systems models. Incor-porate programs with existing IPM programs.	Maintain system and con-tinue to expand other pests.	Maintain system.	Transfer system to permanent support such as State Department of Agriculture, Cooperative Extension Service, Commodity groups, private groups and trouble-shoot system.

V. APPENDICES

APPENDIX A

Sweetpotato Whitefly Research and Action Plan Workshop Steering Committee

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[a] E = Executive Group
R = Resource Group
I = Informational Group

APPENDIX B

Inter-Agency Workshop for the Development of Management and Control Methodologies for the Sweetpotato Whitefly, *Bemisia tabaci.*

February 18-21, 1992
Airport Marriott
Houston, Texas

Local Arrangements by J. Amador, Texas A&M Agricultural Research and Extension Center, and R. Carruthers, USDA-ARS, Subtropical Agricultural Research Laboratory, both of Weslaco, Texas

Program Chairs, R. Carruthers and T. Henneberry
USDA-ARS, Weslaco, TX and Phoenix, AZ

ARS National Program Staff Representatives,
R. Faust and J. Coppedge

Tuesday (PM) February 18

7:00-8:00	Registration
8:00-9:00	Chair/Coordinators/NPS Meeting
9:00 - 11:00	Chemical Trials/Protocols for Ground Application Meeting D. H. Akey

Wednesday February 19

7:00-8:00	On-site Registration (Ballroom Foyer)
8:00-8:05	Call to Order and Administrative Details R. Carruthers/T. Henneberry
8:05-8:15	Welcome and Workshop Charge L. Zannoni, Special Assistant to the Secretary of Agriculture
8:15-8:30	Interagency Cooperation ESCOP, R. Merrifield
8:30-8:45	Workshop Overview/Objectives R. Faust, ARS, Beltsville
	<u>Moderator - R. Faust</u>
8:45-9:00	The Cotton Perspective National Cotton Council Speaker, W. B. Heiden
9:00-9:15	Greenhouse/Floriculture Perspective J. Ellison, floricultural producer
9:15-9:30	Vegetable Perspective Steve Birdsall, Agricultural Commissioner, Imperial Co., CA
9:30-9:45	Peanuts and Miscellaneous Crops B. Lynch, ARS, Tifton, GA
9:45-10:15	Break
	<u>Moderator - R. Carruthers</u>
10:15-10:30	*Bemisia tabaci* vectored plant viruses J. Duffus, ARS, Salinas, CA
10:30-12:00	Panel Discussion: SPW Ecology and Population Dynamics. Coordinators: D. Byrne, Univ. AZ, Tucson, and Steve Naranjo, ARS, Phoenix, AZ. Panel Members: T. Henneberry, M. Johnson, T. Perring, P. Stansly
12:00-1:30	Lunch Break

1:30-3:00 Panel Discussion: Insecticides, Application Technology and and Biorational Chemicals. Coordinators: J. Neal, ARS, Beltsville, MD and N. Toscano, Univ. CA, Riverside. Panel Members: D. Akey, P. Stansly, D. Wolfenbarger, A. Womac

3:00-3:30 Break

3:30-5:00 Panel Discussion: Integrated Crop Management. Coordinators: F. Wilson, ARS, Phoenix, AZ and D. Riley, Texas A&M Research and Extension Center, Weslaco, TX. Panel Members: D. Byrne, H. Flint E. Natwick, D. Schuster and W. Smith

5:30-7:00 Group Dinner. Host: E. King, with comments from Ms. Gen Long, Vice President for Communications, American Agri-Women, and Member of the Users Advisory Board, Mission, TX.

7:00-8:30 Panel Discussion: Integrating Techniques Approaches and Philosophies. Coordinators: D. Haynes, NM State Univ., Las Cruces, and M. Oraze, USDA-APHIS, USDA-APHIS, Hyattsville, MD. Panel Members: J. Allen, J. Amador, C. Kiker and M. Nelson

Thursday February 20

8:00-9:30 Panel Discussion: Biological Control. Coordinators: W. Jones, ARS, Weslaco, TX, L. Osborne, Univ. FL, Apopka, FL, and L. Wendel, APHIS, Mission, TX. Panel Members: K. Heinz, L. Knutson, M. Rose and M. Schauff

9:30-10:00 Break

10:00-11:30 Panel Discussion: Basic Biology/Virus. Coordinators: J. Brown, Univ. AZ, Tucson, AZ, and K. Hoelmer, ARS, Orlando, FL. Panel Members: A. Cohen, J. Duffus, R. Gill and D. Jimenez

11:30-1:00 Banquet Lunch. Host: J. Amador, Texas A&M Research and Extension Center, Weslaco, TX. Guest Speaker: The Honorable E. (Kika) de la Garza, US House of Representatives, Chairman, Committee on Agriculture

1:00-2:45 Breakout Sessions I & II
I-Ecology and Population Dynamics
II-Insecticides, Application Technology and Biorationals

2:45-3:15 Break

3:15-5:00 Breakout Sessions III & IV
III-Integrated Crop Management
IV-Biological Control

7:00-8:45 Breakout Sessions V and VI
V-Basic Biology/Virus
VI-Integrating Techniques

8:45-10:00 Bilateral Meeting - Mexico & APHIS

Friday February 21

8:00-9:00	Working Time for Coordinators
9:00-9:30	Summary: Ecology and Population Dynamics. D. Byrne and S. Naranjo
9:30-10:00	Summary: Insecticides, Application Technology and Biorational Chemicals J. Neal and N. Toscano
10:00-10:30	Summary: Integrating Technologies, Approaches and Philosophies D. Haynes and M. Oraze
10:30-11:00	Summary: Integrated Crop Management D. Riley and F. Wilson
11:00-11:30	Summary: Biological Control W. Jones, L. Osborne and L. Wendel
11:30-12:00	Summary: Basic Biology/Virus J. Brown and K. Hoelmer
12:00-12:30	Concluding Remarks and Adjournment of General Meeting R. Carruthers, R. Merrifield, D. Meyerdirk, J. Amador, R. Riley, D. Kopp, R. Faust
12:30-1:30	Lunch Break
1:30-3:00	Executive Committee Meeting R. Faust, Chair

APPENDIX C

List of Attendees

Inter-agency Workshop for the Development of Management and Control Methodologies for the Sweetpotato Whitefly, *Bemisia tabaci*
February 18-21, 1992
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APPENDIX D

THE ANIMAL AND PLANT HEALTH INSPECTION SERVICE COOPERATIVE ACTION PLAN TO CONTROL THE SWEETPOTATO WHITEFLY

The sweetpotato whitefly (SPW), Bemisia tabaci Gennadius, has recently become a catastrophic pest in a multitude of field crops and greenhouse ornamentals. It is a severe pest across the entire southern United States, particularly in California. A new biotype has increased the damage and necessitated immediate action to control this pest.

Biological control is the principle focus of the Animal and Plant Health Inspection Service (APHIS) cooperative effort to mitigate the economic damage to American agriculture caused by the SPW. This effort involves the introduction, augmentation, and conservation of exotic and native biological control agents (parasitoids, predators and pathogens). Essential support activities, particularly pest and beneficial organism surveys and the compatibility of alternative control methods, are included to assure that biological methods are deployed appropriately.

Introduction of Biological Control Agents

- Collect and rear representative populations of SPW for use in conducting tests to evaluate new biological control agents.

- Collect, ship, and screen for efficacy biological control agents of SPW from foreign locations, probably in the Orient, where the pest originated in contact with a wide range of effective biotic controls.

- Propagate natural enemies that are most likely to control SPW and secure permits for their release in the U.S.

- Evaluate the effectiveness of introduced natural enemies by determining survival, dispersal, levels of parasitization, reductions in crop loss, and the cost/benefit of biological control.

Augmentation of Biological Control Agents

- Conduct small-scale tests to determine predation rates on SPW on Geocoris sp. in alfalfa and citrus, Cryptolaemus sp. on citrus, and Chrysoperla sp. on citrus, winter vegetables, and early season cotton. Predators will be evaluated at critical, low points in pest populations at periods when pesticides are not in use.

- Develop mass-propagation procedures for the most efficacious predators, release large numbers in the field, and determine the cost/benefit of this biological control technology.

- Develop mass-propagation systems for both native and foreign parasites that achieve high levels of SPW control. This will entail efficient SPW mass rearing.

- Test pathogens for use against specific SPW populations and assist in their *in vivo* propagation, formulation, and delivery.

- Evaluate parasitoids, predators, and pathogens following augmentative releases.

Conservation of Biological Control Agents

- Determine the geographical distribution of SPW in the U.S., its alternative habitats, and crop and weed hosts that serve as reservoirs for potential biological control agents.

- Survey SPW in the entire southern U.S. to identify its biological control agents and determine their potential for effecting control in areas experiencing major outbreaks of the pest.

- Determine the ecological requirements of potential biological control agents.

- Conduct biological assessments of cultural practices that might be modified to enhance the effects of natural enemies (i.e., crop sequences, spatial patterns, and planting and harvesting dates).

- Conduct bioassays to determine the effects on biological control agents of insecticides being developed for SPW control. Identify the most selective insecticides, those that provide an adequate level of SPW control yet are least harmful to biological control agents.

Support Activities

- Survey SPW in Mexico, analyze the samples by means of electrophoresis, and classify the specimens as the cotton strain (A) or poinsettia strain (B).

- Identify SPW-transmitted viruses, determine their modes of transmission and recommend action relative to their potential threat to U.S. agriculture. Determine crop and weed hosts that serve as reservoirs of deleterious plant viruses.

- Facilitate and coordinate information and data exchange by all workers involved in the SPW Research and Action Plan.

- Provide education and training in sampling and control methods essential to successful implementation of new SPW control technologies.

- Advertise widely to all SPW workers that the National Biological Control Institute (NBCI) Bulletin Board is operating and is already being used specifically for exchange of SPW information.

APHIS will continue to collect and screen biological control agents of the SPW. Biological control agents have successfully controlled whiteflies in the past and there are many native parasitoids, predators, and pathogens that have not yet been tested. Moreover, foreign exploration, importation, and release of exotic natural enemies is being accelerated. Procedures will be developed to handle, rear, release, and evaluate promising candidates for efficacy against the SPW in California.

APHIS Biological Control Operations will increase work initiated in 1990 at Mission, Texas to coordinate foreign collection, provide quarantine screening, develop suitable rearing capabilities, and distribute experimental populations for testing. The NBCI provided additional funding for this effort in FY 1990 and 1991, and will continue to facilitate coordination and provide scientific consultation for the program. APHIS Methods Development will station a scientist and technical assistant at the ARS field laboratory in Brawley, California, to test biological control agents for use in controlling specific populations of the sweetpotato whitefly.

This is a short term, high intensity initiative intended to identify and capitalize on available options for mitigating current high levels of SPW damage to crops in the Imperial Valley. Concomitantly, existing USDA laboratories will shift resources to increase the collection and testing of new biological control agents for use throughout the range of this pest. APHIS's immediate response capability in California will be augmented and managed from the established Phoenix Methods Development Center. This combined force will accelerate the transfer of control technologies from APHIS biological control operations, ARS research, and associated scientific sources for implementation by Federal and State cooperators, and the private sector.* The objective is to have viable control procedures in use within one to two years.

* Cooperation is maintained with the Agricultural Research Service, Cooperative State Research Service, universities, state departments of agriculture, the biological control industry, affected commodity groups, and individual growers. The USDA emphasizes technology transfer from government research and development to the private sector.

APPENDIX E

D. H. Akey   February 12, 1992, Page 1 of 8 Pages

Protocols for ground application of chemical trials against the sweetpotato whitefly (SPW) in the 1992 growing seasons, as established by the SPW workshop at San Antonio, TX, January 23-24, 1992; revised at SPW workshop at Houston, TX, Feb. 18, 1992, March 12, and 23, 1992. [1]

Introduction

The severity of sweetpotato whitefly (SPW) damage to crops across the Southern US requires that immediate stopgap measures be instituted to reduce this damage. The following protocols for ground application were established in a cooperative effort by the SPW Workshop for Applications of Chemicals Against SPW at San Antonio, TX, January 23-24, 1992, to obtain uniform tests that would generate data useful for comparisons of SPW chemical trials in the 1992 growing seasons on several crops at a number of locations. For some agents, the comparisons will be valid nationwide; for others the comparisons will be restricted to specific locations because of various requirements or conditions. **Sampling units that must be reported are set in bold type.** The latter are a minimum. Investigators are encouraged to report as much detail as possible regarding methods, materials, meteorological conditions during the test periods, and particularly, leaf area of leaves sampled and some indication of the homogeneity of the SPW distribution. It may be necessary to record this information as appendices, but it is important to acquire the data. **Retain raw data and summaries in addition to analyzed data and reports for regulatory agencies; e.g., EPA.** Raw data and summaries are used by them for statistical analysis for making determinations about the efficacy and usefulness of the compounds tested for section 18's and other regulatory categories.

Again, the objectives of the protocols that follow are to insure enough uniformity between trials to make some valid comparisons and draw useful conclusions about compounds, crops, and application methodologies as regards SPW.

The following protocols include, but are not limited to, the crops listed below.

- Cotton
- Peanuts
- Vegetables
  - Tomatoes
  - Eggplant
  - Melons/cucurbits
  - Cole crops
  - Leafy greens.

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[1] Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the USDA and does not imply its approval to the exclusion of other products that may be suitable.

This write up is accompanied by 1) a listing of the chemicals to be tested and the rates for use, 2) the company, the company's product manager, and the company's local technical representative for each geographic area, and 4) a listing of the researchers who have offered or been designated to do the trials. The product managers have offered to provide the compounds. Each researcher will need to communicate with the company contact person to request the amount of material needed for tests. Reseachers should check with the contact person to establish reasonable lead times for requests of materials to assure timely deliveries without "crisis" deadlines.

Protocol I: Standardized sampling counts of SPW. It is preferable to take samples before and after application but at the least sample weekly.

A) **For eggs and immatures, counts will be taken from undersides of leaves.**

1) Counting methods: the counting method chosen is the choice of the investigator. However, **one method must be used consistently during the whole season** to aid statistical analysis; e.g. early in the population increase, it may be easy to do whole leaf counts, but later it may be only practical to do 4 leaf-disc counts/leaf; nevertheless, still make leaf-disk counts early in the season along with the whole leaf counts. This way there will be one counting method to generate data for the entire season analysis; and at the discretion of the investigator, earlier season data may be analyzed by a more sensitive method; e.g., whole leaf counts.

   a) disks; e.g., four 10-mm diam. disks/leaf, one from each leaf quadrant.

   b) grids; superimposed over leaf and counts within grid(s) taken.

   c) whole, half, or partial leaf.

2) Eggs will be reported as **eggs/cm^2**, usually from a fully expanded top leaf.

3) Immatures will be reported as **large nymphs/cm^2**, usually from a fully expanded leaf that has the most large nymphs present; e.g., cotton, typically sampled from a leaf within leaves 1-7 as counted from the top, off the main stem. Based on statistical review of these protocols by a bio-statistician, leaf sampling for immatures should be based on selection of the leaf (leaves) with the most large immatures. This may bias the immature population counts toward the "high" side but will produce more consistent samples with a lower variance than arbitrary selection of a particular leaf as numbered from the top or bottom of the plant. It will also help determine efficacy in the "worst-case scenario". This observation by a bio-statistician is based on a review of data of 2 year's work at three sites by the author and 1 year's work by a colleague at yet another site.

a) Same sampling and counting schemes as for eggs.

b) **Large nymphs will include large 3rd's, small 4th's, and red-eye nymphs (pupae).**

4) Leaf packaging and storage: It is convenient to seal leaves from individual plots in "zip lock" type plastic bags and record the plot and date data, etc., right on the bag with a permanent marker. The material should be kept very cool, but not frozen, from the time of collection in the field and throughout storage in the lab. Leaves should be examined as quickly as possible via a stereo-microscope. This is a time-consuming process--be ready! Bags of leaves need to be examined for mold often, in order to set priorities for counting order (we have been unsuccessful in attempting to count dried leaves. Has anyone tried preservation by alcohol or something similar? Also, fungicidal spray may be useful).

B) **For adults, counts will be taken from yellow sticky cards and will be reported as SPW adults/cm^2.**

1) temporal and spatial parameters

a) **24-hr sample time in 48-hr window.**

b) **Card oriented perpendicular to row in a vertical position with plant.**

c) **Card positioned somewhere between middle to lower third of plant; for low plants such as lettuce and curcubit vines, place cards as needed close to top of plants and use cards appropriately smaller in size if needed.**

d) **Card counted on both sides, area counted to be same throughout season.**

e) Chose "own appropriate size" card and amount of area of the card to count.

2) Source of yellow sticky cards (both sides sticky) and methods of preparation

a) **Olson Products**
P.O. Box 1043
Medina, Ohio 44258
(216) 723-3210
(216) 723-   fax

Both sides sticky: 3" X 5";	No. SS35 box of 100	= $ 24.95
	No. MS35 box of 1000	= $ 199.60
Both sides sticky: 6" X 12";	Pkg. of 10	= $ 16.95
	Pkg. of 50	= $ 49.95
	No. 125-SS 612 box of 125	= $ 109.95
	No. 4MSC case of 4 boxes of 125 cards/box i.e. 500 cards	= $ 362.45

1) Order cards most appropriate in size to use "as is" or to cut to size needed. It may be possible to custom order cards cut to specific sizes.

2) There are sources of cards that are preprinted with a grid but I am unaware of where to obtain such cards that are sticky on both sides.

3) Bring a roll of plastic cling wrap to the field and cover cards with it. Always mark card orientation by a mark or notch and have method for identifying the plot, date, site, etc. The ID can be as simple as ink via a felt pen over the cling wrap (in an area not to be counted to a tiny preprinted label.

4) Cards with SPW are easily kept in a freezer until counted.

5) Grids for counting can be easily scored with a felt-tipped pen right over the cling-wrap, i.e., the wrap does not need to be removed.

6) **Distinguish SPW from banded-wing whitefly (BWWF) or other species in your area for accurate data collection. Other species sometimes occur during specific parts of a season.**

Protocol II: Standardized sampling, replicates, and treatments

A) For eggs and immatures: minimum of 4 replicates (plots)/treatment, and 40 leaves/treatment; e.g., 4 replicates would require 10 leaves picked/replicate but 8 replicates would require 5 leaves/replicate and would result in almost double the degrees of freedom in the statistical analysis of the data.

B) Adults: 1 yellow sticky card/replicate (plot).

Protocol III: Ground Applications (see separate protocols for aerial application)

A) Experimental design:

1) This is left to the discretion of the investigators but considerations should at least be given to the pros and cons of various designs; e.g.,

   a) Random block design with tiers of replicates with treatment position within tiers chosen at random. This design embeds check plots throughout the design and tends to negate effects of non-study parameters, but allows possibility of treatments to influence check plots by changing the populations around them (this has been observed by the author).

   b) Latin square. This places check plots uniformly throughout the design and is strong in reducing non-study parameter effects; check replicates may also be influenced by surrounding treatment replicates as in a). It requires that treatment numbers equal replicate numbers.

   c) Random block design within test blocks of agents with (or believed to have) similar efficacy and separate check block (also laid out in a random block design). Test blocks are positioned for one or two dimensional isolation. A better design is to retain the separate check block but also embed checks within the active treatment blocks.

   d) Regardless of the test design chosen, the investigators must consider the benefits of isolation of plots (replicates) or blocks to reduce the influence of SPW movement between them. For example, in the row crop cotton, lower variance in data was observed in plots isolated by 3-fallow-row corridors and 20-ft alleys than by 2-row-corridors and 3-ft alleys (authors data).

2) The plot size and number of rows have been left to the discretion of the researchers because of the great differences in crop phenologies, morphologies, and systems.

B) Application methods:

1) **List all parameters including:**

   a) **Crop information; e.g., size, stage, fruit, season.**

   b) **Nozzles & types/row.**

   c) **Application equipment and details.**

   d) **Tank pressure in PSI (and if possible delivery PSI).**

   e) **Weather-at time of application.**

f) Calibration.

g) Use only one method of application.

h) **Applications are to be applied by motorized ground equipment, back pack sprayers are not to be used (even if operated by pressurized gas tanks or motorized).**

i) See application protocols (per Al Womac) on determination of particle deposition to report % coverage, droplet size in μg, and total deposition in $\mu g/cm^2$. This must be done at least once in each trial (contact Fred Bouse, ARS, College Station, TX, for technical information).

j) Action thresholds are to be determined by the investigators but must be reported.

C) Chemicals:

1) Chemicals used, follow rates suggested here (chemical list) and by company representative and report each as ai/ac.

2) pH and alkalinity of application (mix) water: sample water and send it out for testing as described in protocol IV. Water should be tested before applications start, during the season if the source changes (e.g., ground to well), probably once during the season or any time that there is cause to question if the water quality has changed significantly. If buffering is required for pH adjustment for pH sensitive products, then consult with company contacts for that product.

3) Leave out adjuvants.

4) Investigators are to individually test the agents identified for inclusion in these tests with the following exceptions.

a) The pyrethroid, fenpropathrin, [Danitol (Valent USA)] has a (and pending) section 18 EPA label(s) that require(s) that it be combined ("tank mixed") with Monitor for use against SPW on tomatoes and with Orthene on cotton.

b) The pyrethroid, bifenthrin, [Capture (FMC Agri. Chem. Group)]. To achieve a fair test, FMC requests that Capture be tested similarly (as Danitol in a), and as an individual agent, if possible.

c) Be aware that individual states may require the same agent to be used with a different name label on different crops; e.g. fenpropathrin (as TAME) and bifenthrin (as BRIGADE), or may have a specific rate that is different from other states for certain crops.

d) Researchers must work closely with the product representatives to be sure that agents are tested relevant to the way the company intends to label them. Researchers are encouraged to test potentially useful combinations as individual agents ("A"), combination ("A" + "B") and agent "B" within the framework of what their resources allow.

e) It is also recognized that some researchers have 1 or more years of data on these combinations, and if that data follows these protocols in general and can be reported in the units called for in these protocols, then combination testing alone may be justified. The supporting data should be furnished as a secondary report with the data generated by these protocols.

D) Application frequency:

1) Ideally, 10 applications are desirable; may be crop dependant.

2) Applications should be made every 7 days if possible but no longer than 14 days should pass between applications (exception is imidacloprid applied as a systemic, then crop should be closely monitored to determine when to initiate foliar sprays).

3) The number of applications may require that a lower rate be used for each application. Do not go below an effective rate for any one application. If the total application amount for the season exceeds the maximum allowed, the treated crop must be destroyed after the end of the experiment as a research trial and must not exceed parameters (e.g. 10 ac in size) that would qualify it as needing an experimental use permit (EUP).

E) Crop Parameters:

1) Yield (in units used for each specific crop).

2) Phytotoxicity, if present; may require rate reduction on sensitive crops.

3) Alteration of plant phenology/morphology, or any other growth differences from the check.

Protocol IV: Testing of application water for pH and alkalinity

A) Container and volume: collect 1 pt. (475 ml) of water in a water tight, thoroughly-rinsed plastic bottle. Let the water run for two minutes before collecting the sample. Fill the container to the very top leaving as little air space as possible so CO_2 in the air does not mix with the water's components and raise its alkalinity.

B) Contact James F. Knauss, Director-Crop Protection Technology, Grace-Sierra Horticultural Products, Iron Run Industrial Park, 6656 Grant Way, Allentown, PA 18106-9316, Telephone (215) 395-7104, fax (215) 395-0322 to inform him of your intent to participate in the water testing program for these national SPW trials.

C) Ship samples to his attention and identify them on both the container label and shipping label as part of the water testing program for the national SPW trials. On the container label, identify yourself, origin, and date of sample (latter two may be coded). Ship to above address.

D) Keep samples cool until shipping. Ship promptly and by overnight courier if possible. Pack bottles properly to reduce movement. Use absorbent material to soak up any leakage.

CROPS AND ASSOCIATED INVESTIGATORS FOR SPW CHEMICAL TRIALS IN THE 1992 GROWING SEASONS, AS ESTABLISHED BY THE SPW WORKSHOP AT SAN ANTONIO, TX, JANUARY 23-24, 1992.

CROP	LOCATION	SEASON	INVESTIGATOR
COTTON	BRAWLEY, CA	SPRING & SUMMER	CHANG-CHI CHU D. H. AKEY T. J. HENNEBERRY
	HOLTVILLE, CA	SPRING & SUMMER	NICK C. TOSCANO ERIC T. NATWICK T. J. HENNEBERRY
	MARICOPA, AZ	SPRING & SUMMER	D. H. AKEY CHANG-CHI CHU T. J. HENNEBERRY
	WESLACO, TX	SPRING, EARLY SUMMER	DAN A. WOLFENBARGER A. N. SPARKS, JR. DAVID G. RILEY
	TIFTON, GA	SPRING & SUMMER	LAURENCE D. CHANDLER
PEANUTS	PEARSALL, TX	SPRING & SUMMER	A. N. SPARKS, JR.
	TIFTON, GA	SPRING & SUMMER	LAURENCE D. CHANDLER GARY A. HERZOG
	N. FLORIDA	SPRING & SUMMER	LANCE OSBORNE
VEGETABLES			
TOMATOES	HOLTVILLE, CA	SPRING	NICK C. TOSCANO ERIC T. NATWICK F. V. SANCES
	QUINCY, FL	FALL	J. E. FUNDERBURK**
	BRADENTON, FL	SPRING & FALL	DAVID J. SCHUSTER
	IMMOKALEE, FL	SPRING	PHILIP A. STANSLY

**This location will only be included if SPW are present.

CROPS AND ASSOCIATED INVESTIGATORS FOR SPW CHEMICAL TRIALS IN THE 1992 GROWING SEASONS, AS ESTABLISHED BY THE SPW WORKSHOP AT SAN ANTONIO, TX, JANUARY 23-24, 1992.

CROP	LOCATION	SEASON	INVESTIGATOR
VEGETABLES (CONTINUED)			
MELONS & CUCURBITS	BRAWLEY, CA	SPRING & FALL	CHANG-CHI CHU D. H. AKEY T. J. HENNEBERRY
	HOLTVILLE, CA	FALL	NICK C. TOSCANO ERIC T. NATWICK T. J. HENNEBERRY
	YUMA VALLEY, AZ		JOHN POLUMBO
ONE CROP IN ONE SEASON. ORDER UNKNOWN.	WESLACO, TX		DAVID G. RILEY
COLE CROPS			
BROCCOLI	BRAWLEY, CA	FALL	CHANG-CHI CHU D. H. AKEY T. J. HENNEBERRY
BROCCOLI	HOLTVILLE, CA	FALL	ERIC T. NATWICK
EGGPLANT	FLORIDA (2 SITES TO BE DETERMINED)	FALL & WINTER	GREGG S. NUESSLY
LEAFY GREENS			
LETTUCE	BRAWLEY, CA		CHANG-CHI CHU D. H. AKEY T. J. HENNEBERRY
LETTUCE	HOLTVILLE, CA		NICK C. TOSCANO ERIC T. NATWICK T. J. HENNEBERRY

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CHEMICALS TO BE TESTED AGAINST SPW IN THE 1992 GROWING SEASONS, AS ESTABLISHED BY THE SPW WORKSHOP AT SAN ANTONIO, TX, JANUARY 23-24, 1992.

COMMON NAME	TRADE NAME	COMPANY	CONTACT
BIFENTHRIN ENDOSULFAN	CAPTURE ®[1] THIODAN ®	FMC CORPORATION Agricultural Chem. Group 1735 Market Street Philadelphia PA 19103	Eunice M. Cuirle, Manager Prod. Develop. and Registration (215) 299-6999 FAX: (215) 299-6577
	BAY NTN-33893	Miles, Inc. Agricultural Chemicals Div. Box 4913 Kansas City, MO 64120	Walter Mullins Insecticide Development Manager (816) 242-2478 FAX: (816) 242-2738
AMITRAZ BUPROFIZEN	OVASYN ™ APPLAUD ®	NOR-AM Chemical Co. 3509 Silverside Rd. P.O. Box 7495 Wilmington, DE 19803	John Lublinkhof Project Manager, Field Div. (302) 575-2058 FAX: (302) 474-2013
FOSETHYL	ALIETTE ®	Rhone-Poulenc Ag Co. P.O. Box 12014 Research Triangle Park, NC 27709	Rich Hanrahan Product Manager, Aliette (919) 549-2626 FAX: (919) 549-4689 (Also Herb Young)
FENPROPATHRIN	DANITOL ®[1]	Valent USA 5910 N. Monroe Fresno, CA 93722	Robert H. Lindemann Sr. Field Research Manager (209) 276-5300 FAX: (209) 276-5320
AZIDIRACHTIN	MARGOSAN-O ®	W. R. Grace Co. 7379 Rt. 32 Columbia, MD 21044	Jim Walter Manager, Bio. Chem. Eng. (410) 531-4582 FAX: (410) 531-4601

[1] These products should be tested in combination with ORTHENE ® (ACEPHATE), or MONITOR ® (METHAMIDOPHOS); see Protocol III C.

CHEMICALS TO BE TESTED AGAINST SPW IN THE 1992 GROWING SEASONS, AS ESTABLISHED BY THE SPW WORKSHOP AT SAN ANTONIO, TX, January 23-24, 1992; FORMULATIONS AND USE RATES, March 12, REVISED APRIL 9, 1992.

COMMON NAME	TRADE NAME & COMPANY	FORMULATION	USE RATE
BIFENTHRIN	FMC CORPORATION CAPTURE ® [1,4]	2 EC (2 LB/GAL)	0.10 LB AI/AC ALONE. 0.08 LB AI/AC + ORTHENE OR MONITOR[1]
	BRIGADE®	10WP-(0.1 LB AI/LB MAT.)	SAME AS CAPTURE
ENDOSULFAN	THIODAN ®	3 EC (3 LB/GAL)	1.0 LB AI/AC
IMIDACLOPRID	MILES, INC. BAY NTN-33893	240 FS (24%, 240 G AI/L)	COTTON: TREATED SEED AT PLANTING, 4 OZ/100 LBS SEED[5]; SIDEDRESS WITH LIQUID 0.25 LB AI/AC AT EARLY SQUARING; FOLIAR SPRAYS AT 0.043 LB AI/AC. VEGETABLES: SPRAY FURROW AT PLANTING AT 0.5 LB AI/AC USING 3 TO 5 IN. BAND ON SEED LINE.
AMITRAZ BUPROFIZEN	NOR-AM CHEMICAL CO. OVASYN ™[6] APPLAUD ®	1.5 LB/GAL S.C. 440 G/L	0.25 LB AI/AC 0.38 LB AI/AC
FOSETHYL - AL	RHONE-POULENC AG CO. ALIETTE ®	80 WDG (5.0 LB Prod./AC)	4.0 LB AI/AC[7]
FENPROPATHRIN	VALENT USA DANITOL ® [1]	2.4 LB AI/GAL	0.2 LB AI/AC + ORTHENE OR MONITOR[1]

ACEPHATE	ORTHENE® [2]	90 S COTTON 75 S OTHER CROPS	0.5 LB AI/AC + DANITOL [OR CAPTURE]
METHAMIDOPHOS	MONITOR® [3]	4 LB AI/GAL	0.75 LB AI/AC + DANITOL [OR BRIGADE OR CAPTURE]
AZIDIRACHTIN	W. R. GRACE CO. MARGOSAN-O ®	0.3%/GAL (9.87 G/GAL)	0.044 LB AI/AC (20 G AI/AC)

1 These products should be tested in combination with ORTHENE ® (ACEPHATE), or MONITOR ® (METHAMIDOPHOS); see Protocol III C.
2 Orthene for cotton, peanuts, lettuce, and other orthene labeled crops.
3 Monitor for tomatoes, cabbage, broccoli and other Monitor labeled crops.
4 Brigade for tomatoes.
5 Contact local rep. for treated cotton seed via Gustafson, Inc.
6 Adjust pH to 7 if pH of water is ≤ 5, optimum = pH 7.
7 If phytotoxicity occurs, cut rate by one-half.

CHEMICAL COMPANIES AND ASSOCIATED CONTACTS FOR SPW CHEMICAL TRIALS IN THE 1992 GROWING SEASONS, AS ESTABLISHED BY THE SPW WORKSHOP AT SAN ANTONIO, TX, JANUARY 23-24, 1992. MARCH 12, 1992

COMPANY	CONTACT	LOCAL CONTACTS	LOCAL CONTACTS
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Procedures to Evaluate Ground and Aerial Spray Equipment in Coordinated Tests of Sweetpotato Whitefly Control

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Chemical Control and Application Technology
Workshop on Sweetpotato Whitefly (SPW)
Holiday Inn Airport
San Antonio, Texas
January 23-24, 1992

Procedures Prepared March 24, 1992

Introduction

The purpose of this spray equipment protocol is to provide standard ground and aerial application methods for the Nationwide Standardized Equipment Tests Against the Sweetpotato Whitefly (SPW). Separate procedures for ground and aerial spray equipment were developed. These tests were established through a cooperative workshop effort (San Antonio, TX, January 23-24, 1992). Test protocol were subsequently modified on February 12, 1992 in a meeting with National Program Staff and Application Technology Research Unit Scientists. It should be noted that the Nationwide Standardized Chemical Tests Against the SPW discussed at the San Antonio meeting is a separate test outlined under a separate protocol written by Dr. David H. Akey (USDA-ARS, Phoenix, AZ). However, SPW sampling methods outlined for the chemical evaluation tests are referenced for use in the equipment tests.

Many equipment, crop, and environmental factors affect spray formation, delivery, and deposit on the intended target. Without control and measurement of these variables, it is difficult to determine whether the differences in control are a result of spray application method, or an overriding factor that affected the deposition of droplets. The spray equipment protocols described herein are outlined as follows:

1. Test Procedures and Sprayer Equipment such as total spray rate, nozzle selection, orientation, operating pressures, calibration, etc. This is outlined on a ground-application basis for four crops. General aerial-application equipment treatments are outlined.

2. Application Variables to Report that are known to affect spraying and spray deposition. This is outlined separately for ground and aerial applications.

3. Spray Deposit Measurement using water-sensitive paper and wash-off from the top and bottom leaf surfaces.

4. Measurement of Biological Effect based on sweetpotato whitefly counts on leaves and sticky cards, per Dr. David Akey's protocol for the chemical evaluation test.

5. Test Matrix of Aerial and Ground Application Equipment by Crop, and scientists indicating participation in test.

Following are the five sections of the protocol:

Ground-Application Test Procedures and Sprayer Equipment

Application Frequency:

For spray deposit assessment of equipment, a minimum of 3 applications is desirable. Crops with wide varying crop canopies during the season and from plot to plot may require more applications. Season long experiments are most ideal.

For biological assessment of equipment, the investigator should consider 10 applications and timing outlined in the chemical evaluation protocol.

Plot Spraying Technique:

Ground-application sprayer traffic through plots may need to be limited only to the pass needed to actually treat the plot. Additional passes through plots to reach other plots may mechanically affect SPW populations.

Calibration:

It should be noted that actual nozzle pressure should be fine tuned by calibrating the sprayer. Actual pressure and ground speed should be within plus or minus 10% of recommended values. Use the following formula to determine the required flowrate (gallons per minute), and hence pressure setting, for each nozzle:

GPM (per nozzle) = (GPA x MPH x W) / 5940

where,

GPM = Gallons Per Minute

GPA = Gallons Per Acre

MPH = Miles Per Hour

W = Row spacing (in inches) divided by the number of nozzles per row.

Calibration should be performed with water by catching and measuring spray output from the nozzle over a 1-minute interval. Before using in-line flowmeters, they also should be calibrated by this method. Also, inaccurate ground speeds often result by selecting engine speed and gear settings with tachometer/speed/gear charts usually located on the console of the tractor or sprayer. **Ground speed should be calibrated by driving over a soil surface representative of field while measuring time and distance.**

Ground-Application Test Procedures and Sprayer Equipment cont:

Specifications of sprayer equipment are outlined for four crops:

Cotton:

1.	Equipment	Drop Nozzles FMC Degania Air Boom Berthoud Cannon Air Boom
2.	Total Spray Rate	20 gpa

Peanuts:

1.	Equipment	Drop Nozzles FMC Degania Air Boom B.E.I. Proptec Sukup Bug Beater & Spray Attachment
2.	Total Spray Rate	20 gpa

Tomatoes:

1.	Equipment	Drop Nozzles Berthoud Tomato Air Boom Sukup Bug Beater & Spray Attachment
2.	Total Spray Rate	30 gpa per foot of canopy height, except 30 gpa for Sukup Bug Beater

Melons & Cucurbits:

1.	Equipment	Drop Nozzles FMC Degania Air Boom B.E.I. Proptec
2.	Total Spray Rate	30 gpa

All Crops:

3.	Sprayer Calibration	Before each treatment using water as test liquid.
4.	Chemical/Rate	Discretion of the researcher. Constant for all treatments per test.
5.	Adjuvants	None
6.	Plot Size	100 ft long, minimum 25 ft (8 rows), minimum
7.	Crop/Foliage	Uniform crop and foliage development between treatments.
8.	Experimental Design	Randomized Complete Block 4 - replications minimum

Ground-Application Test Procedures and Sprayer Equipment cont:

Note: Double check total spray rate by calibrating sprayer as previously described.

Cotton - (Row Spacing 40 inches):

Sprayer	**Drop-nozzle sprayer**
Total Spray Rate	**20** gallons per acre.
Nozzle Selection	**Spraying Systems* TX-10 hollow cone**
Number of Nozzles per Row	3
Nozzle Capacity	**0.18** gallons per minute
Nominal Nozzle Pressure	**50** pounds per square inch
Ground Speed	**4** miles per hour
Nozzle Location	1 overtop, 2 dropped
Nominal Nozzle Distance to Canopy	Top nozzle 12 inches above plant canopy.

*Disclaimer: Mention of a trademark, vendor, or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Dept. of Agric. and does not imply its approval to the exclusion of other products that may also be suitable.

Ground-Application Test Procedures and Sprayer Equipment cont:

Note: Double check total spray rate by calibrating sprayer as previously described.

Cotton - (Row Spacing 40 inches):

Sprayer	**FMC Degania Air Boom**
Total Spray Rate	**20** gallons per acre.
Nozzle Selection	**Spraying Systems 8002 flat fan**
Number of Nozzles per Row	**4** over-the-top
Nozzle Capacity	**0.17** gallons per minute
Nominal Nozzle Pressure	**30** pounds per square inch
Ground Speed	**5** miles per hour
Nozzle Location	4 overtop
Nominal Nozzle Distance to Canopy	20 inches above plant canopy.

Ground-Application Test Procedures and Sprayer Equipment [cont]:

Note: Double check total spray rate by calibrating sprayer as previously described.

Cotton - (Row Spacing 40 inches):

Sprayer	**Berthoud Cannon Air Boom**
Total Spray Rate	**20** gallons per acre.
Nozzle Selection	**Air Shear Nozzle supplied with sprayer**
Number of Nozzles per Row	2 over-the-top
Nozzle Capacity	**0.34** gallons per minute
Nominal Nozzle Pressure	Custom calibrate
Ground Speed	**5** miles per hour
Nozzle Location	2 overtop
Nominal Nozzle Distance to Canopy	20 inches above plant canopy.

Ground-Application Test Procedures and Sprayer Equipment cont:

Note: Double check total spray rate by calibrating sprayer as previously described.

Peanuts - (Row Spacing 36 inches, on 72-inch beds):

Sprayer	**Drop-nozzle sprayer**
Total Spray Rate	20 gallons per acre.
Nozzle Selection	**Spraying Systems* TX-8 hollow cone**
Number of Nozzles per Row	3
Nozzle Capacity	0.16 gallons per minute
Nominal Nozzle Pressure	60 pounds per square inch
Ground Speed	4 miles per hour
Nozzle Location	1 overtop, 2 dropped
Nominal Nozzle Distance to Canopy	12 inches above plant canopy.

Ground-Application Test Procedures and Sprayer Equipment [cont]:

Note: Double check total spray rate by calibrating sprayer as previously described.

Peanuts - (Row Spacing 36 inches, on 72-inch beds):

Sprayer	**FMC Degania Air Boom**
Total Spray Rate	**20** gallons per acre.
Nozzle Selection	**Spraying Systems 8002 flat fan**
Number of Nozzles per Row	**4** over-the-top
Nozzle Capacity	**0.17** gallons per minute
Nominal Nozzle Pressure	**30** pounds per square inch
Ground Speed	**5** miles per hour
Nozzle Location	4 overtop
Nominal Nozzle Distance to Canopy	20 inches above plant canopy.

Ground-Application Test Procedures and Sprayer Equipment cont:

Note: Double check total spray rate by calibrating sprayer as previously described.

Peanuts - (Row Spacing 36 inches, on 72-inch beds):

Sprayer	**B.E.I. Proptec**
Total Spray Rate	20 gallons per acre.
Nozzle Selection	**Rotary atomizer**
Number of Nozzles per Row	1
Nozzle Capacity	0.61 gallons per minute
Nominal Nozzle Pressure	Custom calibrate peristaltic pump
Ground Speed	5 miles per hour
Nozzle Location	1 overtop
Nominal Nozzle Distance to Canopy	20 inches above crop canopy.

Ground-Application Test Procedures and Sprayer Equipment cont:

Note: Double check total spray rate by calibrating sprayer as previously described.

Peanuts - (Row Spacing 36 inches, on 72-inch beds):

Sprayer	**Sukup Bug Beater & Spray Attachment**
Total Spray Rate	**20 gallons per acre.**
Nozzle Selection	**Spraying Systems 80015 flat fan**
Number of Nozzles per Row	2 dropped
Nozzle Capacity	0.18 gallons per minute
Nominal Nozzle Pressure	60 pounds per square inch
Ground Speed	3 miles per hour
Nozzle Location	2 dropped
Nominal Nozzle Distance to Canopy	12 inches from canopy

Ground-Application Test Procedures and Sprayer Equipment cont:

Note: Double check total spray rate by calibrating sprayer as previously described.

Tomatoes - (Row Spacing 60 inches):

Sprayer	Drop-nozzle sprayer
Total Spray Rate	(30 gallons per acre) per foot canopy height.
Nozzle Selection	Albuz ATR Red
Number of Nozzles per Row	2 dropped per foot of canopy height
Nozzle Capacity	0.61 gallons per minute
Nominal Nozzle Pressure	190 pounds per square inch
Ground Speed	4 miles per hour
Nozzle Location	2 dropped per foot canopy height
Nominal Nozzle Distance to Canopy	Drop nozzle 12 inches from canopy

Ground-Application Test Procedures and Sprayer Equipment cont:

Note: Double check total spray rate by calibrating sprayer as previously described.

Tomatoes - (Row Spacing 60 inches):

Sprayer	**Berthoud Tomato Air Boom**
Total Spray Rate	**(30 gallons per acre) per foot canopy height.**
Nozzle Selection	**Air Shear Nozzle supplied with sprayer**
Number of Nozzles per Row	2 dropped per foot of canopy height
Nozzle Capacity	0.61 gallons per minute
Nominal Nozzle Pressure	Custom calibrate
Ground Speed	4 miles per hour
Nozzle Location	2 dropped per foot canopy height
Nominal Nozzle Distance to Canopy	12 inches from canopy

Ground-Application Test Procedures and Sprayer Equipment cont:

Note: Double check total spray rate by calibrating sprayer as previously described.

Tomatoes - (Row Spacing 60 inches):

Sprayer	**Sukup Bug Beater & Spray Attachment**
Total Spray Rate	**30 gallons per acre.**
Nozzle Selection	**Spraying Systems 8004 flat fan**
Number of Nozzles per Row	2 dropped
Nozzle Capacity	0.45 gallons per minute
Nominal Nozzle Pressure	50 pounds per square inch
Ground Speed	3 miles per hour
Nozzle Location	2 dropped
Nominal Nozzle Distance to Canopy	12 inches from canopy

Ground-Application Test Procedures and Sprayer Equipment cont:

Note: Double check total spray rate by calibrating sprayer as previously described.

Melons/Cucurbits - (Row Spacing 80 inches on beds)

Sprayer	Drop-nozzle sprayer
Total Spray Rate	30 gallons per acre
Nozzle Selection	Spraying Systems TX-18 hollow cone
Number of Nozzles per Row	3
Nozzle Capacity	0.40 gallons per minute
Nominal Nozzle Pressure	75 pounds per square inch
Ground Speed	3 miles per hour
Nozzle Location	1 overtop, 2 dropped
Nominal Nozzle Distance to Canopy	Top nozzle 12 inches above plant canopy.

Ground-Application Test Procedures and Sprayer Equipment cont:

Note: Double check total spray rate by calibrating sprayer as previously described.

Melons/Cucurbits - (Row Spacing 80 inches on beds)

Sprayer	**FMC Degania Air Boom**
Total Spray Rate	30 gallons per acre
Nozzle Selection	Spraying Systems 8002 flat fan
Number of Nozzles per Row	8 over-the-top
Nozzle Capacity	0.25 gallons per minute
Nominal Nozzle Pressure	60 pounds per square inch
Ground Speed	5 miles per hour
Nozzle Location	8 overtop
Nominal Nozzle Distance to Canopy	Top nozzle 20 inches above plant canopy.

Ground-Application Test Procedures and Sprayer Equipment cont:

Note: Double check total spray rate by calibrating sprayer as previously described.

Melons/Cucurbits - (Row Spacing 80 inches on beds)

Sprayer	**B.E.I. Proptec**
Total Spray Rate	30 gallons per acre
Nozzle Selection	**B.E.I. Rotary Atomizer**
Number of Nozzles per Row	1
Nozzle Capacity	2.02 gallons per minute
Nominal Nozzle Pressure	Custom calibrate peristaltic pump
Ground Speed	5 miles per hour
Nozzle Location	1 overtop
Nominal Nozzle Distance to Canopy	20 inches above plant canopy.

Ground-Application Information to Report:

1. Crop sprayed.
2. Sprayer equipment description including brand, design, number of rows, etc.
3. If air-assisted, air velocity measured at spout exit, orientation of airstream, air volume, nozzle orientation in airstream, distance from canopy, etc.
4. Total spray rate (gpa).
5. Nozzle description, including brand, type, and nozzle number.
6. Number of nozzles per row.
7. Nozzle capacity (gpm).
8. Nozzle pressure.
9. Ground speed.
10. Nozzle location.
11. Nozzle orientation.
12. Nominal nozzle distance to canopy.
13. Chemical or tracer sprayed and amount of active ingredient applied per acre.
14. Crop planting date, initial and final dates of tests.
15. Crop height, row spacing, amount of overlap, or gap.
16. Crop description in terms of fruiting, foliage development, and canopy support with stakes, trellises, strings, etc.
17. Maximum and minimum temperatures during tests.
18. Maximum and minimum relative humidity during tests.
19. Wind velocity and direction during spray applications.
20. Location for water-sensitive paper and plant wash samples.
21. Number of water-sensitive paper examined.
22. Method of water-sensitive paper analysis.
23. Mean water-sensitive paper coverage for each treatment, coverage computed as area of spots divided by total scanned area (expressed as percent).
24. Number of plant washes to measure spray deposit on top and bottom of leaf.
25. Method of spray deposit plant wash analysis.
26. Mean spray deposit for each treatment expressed as micro-grams per square centimeter ($\mu g/cm^2$).
27. Mean sweetpotato whitefly counts before and after spray application.

Aerial-Application Test Procedures and Sprayer Equipment

Many variables affect the calibration of aircraft. Determining swath width and nozzle placement for uniformity of deposit is usually performed on a trial and error basis for each aircraft. **Use the following formulas to determine the required flowrate and nozzle selection.**

GPA = GPM (all nozzles) / APM

where,

GPA = Gallons Per Acre

GPM = Gallons Per Minute

APM = Acres Per Minute.

APM = (SW (ft) x MPH) / 495

where,

APM = Acres Per Minute

SW = Swath Width (ft)

MPH = ground speed in Miles Per Hour

GPM (per nozzle) = GPM (all nozzles) / N

where,

GPM = Gallons Per Minute

N = Number of nozzles

Calibration should be performed with water by making trial flights with spray over a known distance, and swath width, and computing gallons per acre based upon the refill of the aircraft and area sprayed.

Aerial-Application Test Procedures and Sprayer Equipment

Aerial application tests are planned for four crops:

Cotton:

1.	Equipment	Conventional Chimavir Boom Winglets Rotary Nozzles

Peanuts:

1.	Equipment	Conventional Chimavir Boom Winglets

Tomatoes:

1.	Equipment	Conventional versus Ground Spray

Melons & Cucurbits:

1.	Equipment	Conventional Chimavir Boom Winglets

All Crops:

2.	Total Spray Rate	5 gpa for all equipment.
3.	Sprayer Calibration	Before each treatment using water as a test liquid.
4.	Chemical/Rate	Discretion of the researcher. Constant for all treatments per test.
5.	Adjuvants	None
6.	Plot Size	5 acres, minimum
7.	Crop/Foliage	Uniform crop and foliage development between treatments. Measure and report row spacing, crop height and amount of row lap/ or gap.
8.	Experimental Design	Randomized Complete Block 4 - replications minimum

SINCE DIFFERENT TYPES AND MAKES OF AIRCRAFT WILL BE USED IN THE AERIAL TEST, SPECIFIC NOZZLES WILL NOT BE SPECIFIED SINCE NOZZLE SELECTION DEPENDS ON SPEED AND SWATH WIDTH. SPEED AND SWATH WIDTH VARY WITH AIRCRAFT TYPE AND MAKE.

Aerial-Application Information to Report:

1. Crop sprayed.
2. Aircraft description including make, model, etc.
3. Description of aircraft operation (eg. flaps down X number of degrees, etc).
4. Total spray rate (gpa).
5. Nozzle description, including brand, type (flat fan, hollow cone, rotary, etc.), and size.
6. Orientation of spray output.
7. Number of nozzles and nozzle mounting position (eg. 50 nozzles on 6-in. centers on standard boom and mount. Boom extending to one-half aileron. Boom located 8 in. astern and below wing trailing edge, etc.).
8. Spray swath width (feet) from aircraft.
9. Nozzle operating pressure.
10. Calibrated flowrate of nozzles.
11. Airspeed, and true groundspeed of spray application.
12. Height of application measured from canopy to boom.
13. Chemical or tracer sprayed and amount of active ingredient applied per acre.
14. Mean hopper load per plot.
15. Direction of spray flight lines with respect to rows (parallel, perpendicular, X degrees, etc.)
16. Crop planting date, initial and final dates of tests.
17. Crop height, row spacing, amount of overlap.
18. Crop description in terms of fruiting, foliage development, and canopy support with stakes, trellises, strings, etc.
19. Maximum and minimum temperatures during tests.
20. Maximum and minimum relative humidity during tests.
21. Wind velocity and direction during spray applications.
22. Location for water-sensitive paper and plant wash samples.
23. Number of water-sensitive paper examined.
24. Method of water-sensitive paper analysis.
25. Mean water-sensitive paper coverage for each treatment, coverage computed as area of spots divided by total scanned area (expressed as percent).
26. Number of plant washes to measure spray deposit on top and bottom of leaf.

Aerial-Application Information to Report cont.:

27. Method of spray deposit plant wash analysis.
28. Mean spray deposit for each treatment expressed as micro-grams per square centimeter ($\mu g/cm^2$).
29. Mean sweetpotato whitefly counts before and after spray application.

Spray Deposit Measurement

The physical spray deposit should be measured by the following two methods:

1. Water-Sensitive Paper

2. Residue Washed from Top and Bottom of Plant Surfaces.

Ideally, spray deposit with both methods in all plots is desireable. Monitoring the deposit by each method requires sampling at a location in the plant canopy consistent with where the SPW is sampled.

Water-Sensitive Paper

Generally, the SPW resides on the underside of leaves, and in shaded areas on the underside of the plant. Water-sensitive paper should be fastened to the underside of the leaf, or the plant surface where the SPW resides, with the yellow side facing towards the ground. Place the paper in the canopy where the whiteflys will be sampled.

Fasten each paper with a lightweight paper clip so that the leaf does not droop, and so that the paper and clip do not interfere with the free movement of the leaf. Clipping the paper on the leaf near the petiole usually minimizes the paper effect. Much discussion has centered on the influence of the weight of the paper on the orientation and dynamic response of the leaf during spraying. The paper will alter the leaf response. However, it is the opinion of the authors that the deposit on the paper will generally represent what reaches the underside of leaves in many crops.

Be prepared to accept the fact that it is often so humid in the canopy that your papers will all turn blue.

Spray Deposit Measurement cont:

The number of water-sensitive paper per plot is left to the discretion of the researcher. The authors have typically placed 20 per location per plot in cotton plots. It would be ideal to pre-test deposit variability per plot by spraying one or two plots containing many papers. This may be necessary to determine if the test has the statistical precision to determine deposit differences between plots.

Water-sensitive paper (3 by 2 inch, Part No. 20301-2) is available through distributors of:

Spraying Systems Co.
North Avenue
Wheaton, Illinois 60188
Telephone: (312) 665-5000

Dr. Eric Franz (USDA-ARS, College Station, Texas) developed a technique which uses a commercially-available, hand-held image scanner and a personal computer to evaluate card coverage. **Dr. Franz can be contacted for scanner details and the schedule of user-training.**

Residue Washed from Plant Surfaces

The actual spray deposit should be washed from an undisturbed leaf in a location similar to where the water-sensitive paper is mounted. The most consistent results will be obtained if the deposit is washed from a known, constant leaf area. Disks can be cut from leaves, but separating the residue from the top and bottom surfaces can be difficult. The number of washes may need to be determined in the same manner as described for the water-sensitive paper.

Dr. Jim Carlton (USDA-ARS, College Station, Texas) designed an inexpensive spray deposit sampler for top and bottom leaf surfaces. **Dr. Carlton can be contacted for sampler design and a reprint of user-instructions.**

Measurement of Biological Effect:

Use Dr. David Akey's sweetpotato whitefly sampling protocol developed for the chemical evaluation test as a basis for determining the biological effect of application method. The authors leave to the discretion of the investigator where to sample eggs and immatures in the plant canopy and whether yield is to be measured.

Test Matrix of Aerial and Ground Application Equipment by Crop, and scientists indicating participation in test.

GROUND		AERIAL	
Cotton		**Cotton**	
Drop Nozzles	Akey, Riley, Wright, Sumner, Herzog, & Womac	Conventional	Bouse, Wright, & Wolfenbarger
FMC Degania Air Boom	Wright, Sumner, Herzog, & Womac	Chimavir Boom Winglets	Bouse, Wright, & Wolfenbarger
Berthoud Cannon Air Boom	Akey, Riley, Sumner, Herzog, & Wright	Rotary Nozzle	Bouse & Wolfenbarger
Peanuts		**Peanuts**	
Drop Nozzles	Chandler, Sumner, & Womac	Conventional	Chandler, Sumner, & Womac
FMC Degania Air Boom			
B.E.I. Proptec		Chimavir Boom Winglets	
Sukup Bug Beater & Spray Attachment			
Tomatoes		**Tomatoes**	
Drop Nozzle	Stansley & Sances	Conventional	Sances
Berthoud Tomato Air Boom			
Sukup Bug Beater & Spray Attachment			
Melons and Cucurbits		**Melons and Cucurbits**	
Drop Nozzle	Riley, Sumner, & Womac	Conventional	Bouse & Wright
FMC Degania Air Boom	Wright, Sumner, & Womac	Chimavir Boom Winglets	
B.E.I. Proptec	Sumner & Womac		

Note: See the Appendix for manufacture's literature on ground application equipment.

United States Department of Agriculture

Agricultural Research Service

National Program Staff

Beltsville, Maryland 20705

January 30, 1992

SUBJECT: Coordination Meeting for 1992 Residue and Efficacy Field Trials with Chemicals, Insect Specific Fungi and Improved Application Technology for the Sweetpotato Whitefly (SPW)

TO: Howard J. Brooks, Acting ADA
Plant Sciences

FROM: James R. Coppedge, NPL JRC
Applied Entomology-Plants

The subject meeting was held in San Antonio, Texas, at the Airport Holiday Inn, January 23 and 24, 1992. A list of attendees is attached. Listed below in tabular form are the cooperative tests planned in 1992, the commodity involved, the agencies and/or university involved and the lead scientist for the project. The person identified after the project title is the coordinator for that research thrust. Specific protocols for the various research areas are being developed by the coordinators.

I. Field development of residue samples to accelerate the registration process for bifenthrin and imidacloprid (NTN-33893). (P. Schwartz, IR-4 Program ARS, Beltsville, MD).

Location	Commodity	Agency/Univ.	Activity
Imidacloprid:			
Salinas, CA	Pepper/tomato/squash	ARS	Field residue
Irvine, CA	Cantaloupe/cucumber	Univ. of CA	Field residue
Charleston, SC	Pepper/tomato/squash cantaloupe/cucumber	ARS	Field residue
Gainesville, FL	Pepper/tomato/squash cantaloupe/cucumber	Univ. of FL	Field residue
Weslaco, TX	Pepper/tomato/squash cantaloupe/cucumber	ARS	Field residue
Bifenthrin:			
Tifton, GA	Peanuts/cabbage	ARS-UG	Field residue
Charleston, SC	Cabbage	ARS	Field residue
Weslaco, TX	Cabbage	ARS	Field residue
College Station, TX	Peanuts	TAMU	Separation oil-solids
East Lansing, MI	Peanuts/cabbage	Mich. State	lab analysis

1/31/92
038-NPB

II. Standardized Test for Evaluation of Selected Pesticides for Suppression of Sweetpotato Whitefly (D. Akey, ARS, Phoenix, AZ)

Crop	Location	Agency/Inst.	Investigator(s)
Cotton	Brawley, CA	ARS	Chu-Akey-Henneberry
	Maricopa, AZ	ARS	Chu-Akey-Henneberry
	Holtville, CA	UCR	Toscano
	Weslaco, TX	ARS-TAMU	Wolfenbarger-Riley-Sparks
	Tifton, GA	ARS-UG	Chandler-Herzog
Tomatoes (Spring)	Holtville, CA	UCR	Toscano
(Spring)	Innokalee, FL	UF	Stansly
(Fall)	Bradenton, FL	UF	Shuster
(Fall)	Quincy, FL	UF	Funderburt
Melons	Weslaco, TX	TAMU	Riley
	Brawley, TX	ARS	Chu-Akey-Henneberry
	Holtville, CA	UCR	Toscano
Cole crops (cabbage)	Weslaco, TX	TAMU	Riley-Sparks
(broccoli)	Brawley, CA	ARS	Chu-Akey
	Florida (2 trials)	UF	Leivee-Nuessly
	Holtville, CA	UCR	Toscano
Peanuts	Tifton, GA	ARS-UG	Chandler-Herzog
	Pearsall, TX	TAMU	TBD
Leafy Greens (lettuce,	Holtville, CA	UCR	Toscano, et. al.
etc.)	Brawley, CA	ARS	Chu, et. al.

III. Efficacy of Imidacloprid and bifenthrin against the Sweetpotato Whitefly (in Conjunction with IR-4 Studies, P. Schwartz, IR-4 ARS Coordinator)

Location	Commodities(y)	Agency/Inst.	Investigator(s)
Imidacloprid:			
Salinas, CA	Pepper/tomato/squash	ARS	TBD
Irvine, CA	Cantaloupe/cucumber	UC	Bailey
Charleston, SC	Pepper/tomato/squash cantaloupe/cucumber	ARS	Shalk/Elsey
Gainesville, FL	Pepper/tomato/squash cantaloupe/cucumber	UF	Johnson
bifenthrin:			
Tifton, GA	Peanuts/cabbage	ARS-UG	Chandler-Herzog
Charleston, SC	Cabbage	ARS	Shalk
Weslaco, TX	Cabbage	ARS	Coleman

IV. Small Plot Field Evaluations of an Insecticidal Extract of *Nicotinia* sp. Against the Sweetpotato Whitefly (J. Neal, ARS, Beltsville, MD)

Location	Crop	Agency/Inst.	Investigator(s)
Stoneville, MS	Cotton (also cotton aphid)	ARS	Hardee
Holtville, CA	Lettuce/melons	UCR	Toscano
Immokalee, FL	Tomatoes (also thrips palmi)	UF	Stansly
Immokalee, FL	Melons	UF-ARS	Stansly-Hoelmer

V. Large Plot Field Evaluations of *Buevaria bassianna* Against the Sweetpotato Whitefly (J. Wright, ARS, Weslaco, TX)

Location	Crop	Agency/Inst.	Investigator(s)
Orlando, FL	Tomatoes/cantaloupe	ARS	Hoelmer
Brawley, CA	Cotton/cantaloupe/lettuce	ARS	Chu-Akey
Tifton, GA	Peanuts	ARS-UG	Chandler/Herzog
Weslaco, TX	Cotton	ARS	Wright
Weslaco, TX	Vegetables (TBD)	ARS-TAMU	Carruthers/Riley
Pearsall, TX	Peanuts	TAMU	TBD
Charleston, SC	Mixed greens	ARS	Elsey

VI. Small Plow Field Evaluation of *Paecilomyces fumosorseus* (PFR) (supplied by W. R. Grace Co.) for Control of Sweetpotato Whitefly (Lance Osborne, UF, Apopka, FL)

Location	Crop	Agency/Inst.	Investigator(s)
Stoneville, MS	Cotton	ARS	Hardee
Holtville, GA	Cabbage/cotton/lettuce	UCR	Natwick
Brawley, CA	Cotton	ARS	Chu
Weslaco, TX	Cabbage/melons	ARS	Carruthers
Florida	Vegetables (4 types TBD)	UF	Nuessley-Shuster Stansly-Osborne Hoelmer

VII. Initiation of Sweetpotato Whitefly Resistance Monitoring Program (Vial Test) (Wolfenbarger, ARS, Weslaco, TX; Riley, TAMU, Weslaco, TX, and Ed Gage, FMC Corp., San Antonio, TX)

Location	Agency/Institution	Investigator(s)
CA and AZ	ARS-UCR	Akey-Tóscano
Florida	UF (2 sites)	Osborne-Stansly
Georgia	UG	Herzog
Texas	ARS-TAMU	Wolfenbarger-Riley
New York	Cornell	Sanderson

Howard J. Brooks

VIII. Field Evaluation of Application Equipment for Improved Pesticide Deposition and Improved Sweetpotato Whitefly Control (Al Womac, ARS, Stoneville, MS)

Type of Applicator	Location	Crop	Agency/Inst.	Investigator
Ground:				
Drop Nozzle	All	(Standard)		
FMC Degania	Weslaco, TX	Cotton	ARS	Wright
FMC Degania	Stoneville, TX	Cotton	ARS	Womac
Berthoud	Phoenix, AZ	Cotton	ARS	Akey
Berthoud	Weslaco, TX	Cotton	TAMU	Riley
Berthoud	Weslaco, TX	Cotton	ARS	Wright
Berthoud	Immokalee, FL	Veg.	UF	Stansly
D&W Industries	Stoneville, MS	Veg.	ARS	Womac
Gervan	Stoneville, MS	Veg.	ARS	Womac
Suckup	Immokalee, FL	Veg.	UF	Stansly
Electrostatic	Holtville, CA	Veg.	UCR	Sances
Electrostatic	Weslaco, TX	Veg.	TAMU	Riley
Electrostatic	Immokalee, FL	Veg.	UF	Stansly
Air:				
Conventional aircraft	Weslaco, TX	Cotton	ARS	Wolfenbarger
Fixed wing-flaps down	Weslaco, TX	Cotton	ARS	Fronze, Bouse (chemicals)
Rotary-slow	Weslaco, TX	Cotton	ARS	Wright
Rotary-Israel deflector	Weslaco, TX	Cotton	ARS	Fronze, Bouse (Bauvaria)
Aerial vs. Ground	Holtville, CA	Tomatoes	UCR	Sances

As you can see we have a very ambitious program for 1992. This research will be supported in part by the ARS contingency funds, in part by Fermone Corp. (some of the Beauvaria studies) and in part by base funds. I will cover how the contingency funds are to be distributed in a separate memo.

Enclosure

cc:
R. Parry
P. Schwartz
All Attendees
J. Antognini
R. Faust
E. Corley
F. Horn
R. Reginato
P. Putnam
E. Finney

San Antonio Meeting - January 23, 1992

Name	Address	AFF	Telephone/FAX
James R. Coppedge	Bldg. 005, Rm. 212, BARC-West Beltsville, MD 20705	USDA-ARS	301/504-5541 301/504-5467
George W. Pittarelli	Bldg. 009, Rm. 402, BARC-West Beltsville, MD 20705	USDA-ARS	301/504-6478
J. F. Knauss	6656 Grant Way, Allentown, PA 18106-9316	Grace- Sierra	215/395-7104
Edgar G. King	2301 S. Intnl. Blvd. Weslaco, TX 78596	USDA-ARS	512/564-2423 512/565-6133
Alvin R. Womac	Application Tech. Res. P.O. Box 350, Stoneville, MS	USDA-ARS	601/686-5364 601/686-9406
Joseph E. Mulrooney	Same as Womac	USDA-ARS	601/686-5342 601/686-9406
C. C. Chu	4151 Hwy. 86, Brawley, CA 92227	USDA-ARS	619/344-4184
Dan Wolfenbarger	2413 Highway 83 East Weslaco, TX 78596	USDA-ARS	512/969-4828 512/565-6133
L. W. Kirk	231 Scoates TAMU College Station, TX 77843	ARS	409/260-9364
D. D. Hardee	P.O. Box 346 Stoneville, MS 38776	USDA-ARS	601/686-5231 601/686-5421
R. J. Coleman	2301 S. Intnl. Blvd. Weslaco, TX		512/565-2423 512/565-6133
P. A. Stansly	P.O. Drawer 5127 Immokalee, FL 33934		813/657-5221 813/657-5224
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San Antonio Meeting - January 23, 1992

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APPENDIX F

Sweetpotato Whitefly ad hoc Working Group Meeting
October 24-25, 1991
Atlanta, Georgia

Summary

Drs. R. Faust and J. Coppedge (USDA-ARS National Program Leaders) called the meeting to initiate ARS planning for sweetpotato whitefly (SPW) research. Twenty-six scientists, representing ARS, APHIS, State Experiment Stations and various commodity groups participated in the meeting. The original goal of this meeting was to acquire input from cooperative agencies into on-going and future SPW activities and to initiate an effort to develop a 5 year Research Action Plan that would guide ARS programs. Immediate interest arose from the group about the need for a larger scale planning activity that would cover all agencies involved in SPW research. D. Meyerdirk (USDA-APHIS) suggested that the plan cover both research and implementation efforts. R. Faust and J. Coppedge suggested that we explore the option of a cooperative plan but that ARS was still responsible for the development of an internal agency plan. However, by the end of the meeting it was well accepted that an interagency planning process should be pursued and that ARS would organize the meeting.

The meeting proceeded through brief presentations by individual scientist representing different geographic areas of the US currently plagued by SPW. D. Mayer and K. Hoelmer addressed the situation in Florida. It was stated that insecticides currently provided little control in many areas, although Monitor and Danitol seemed to provide the best activity. Growers using soaps and oils also had some success but phytotoxicity was noted in several cases. Additional information was discussed on biological control agents being tested in California, Florida and Texas. Parasitoids, predators and pathogens were all thought to hold potential for control. J. Neal discussed plant extracts that cause rapid acute mortality of immature SPW. He said that these materials were now being characterized and considered for patents. T. Henneberry, D. Byrne, S. Birdsall, N. Toscano and J. Duffus addressed the problems in Arizona and California where the SPW had severely damaged both cotton and vegetable crops. Continuous movement of adults between crops in both space and time, was felt to be one of the primary factors limiting control. Alteration of plowing times, planting schedules, and other cultural practices to minimize SPW invasion were thought to aid producers in the Rio Grande Valley (RGV) of Texas. J. Amador said that cultural practices were some of the best tactics developed by the SPW Task Force that is currently helping growers deal with the problem in his area. R. Carruthers provided an overview of new programs initiated by ARS in the RGV and summarized the European Biological Control Laboratories foreign exploration program for natural enemies. Several exotic parasitoids and pathogens were already in ARS quarantine. Additional summaries were also made by the commodity groups, emphasizing the both short- and long-term answers were needed and by USDA-APHIS, who stressed the need biological control implementation programs. J. Duffus stressed the need for virology efforts.

Based on group discussions, 5 Action Areas were identified for the proposed workshop: 1- Ecology/ population dynamics; 2- Fundamental biology/ virology; 3- Integrated crop management; 4- Chemical control; and 5- Biological control. If the proposed workshop were approved, R. Carruthers and T. Henneberry were to organize this interagency activity in Houston based on the above action areas and an agenda developed by the group. Potential subject area coordinators were identified from various agencies to aid in the development of a written action plan and with the workshop. J. Amador and R. Carruthers volunteered to take care of local arrangements and T. Henneberry volunteered to put together a draft action plan.

Sweetpotato Whitefly Workshop Planning Committee Meeting

Holiday Inn North - Hartsfield International Airport
Atlanta, Georgia
24-25 October 1991

Tentative Agenda

Thursday, 24 October

8:00 am - 8:30 am	Meeting Registration	
8:30 am - 8:40 am	Welcome/Introductions	R. Carruthers/ T. Henneberry
8:40 am - 8:50 am	Meeting Objectives	R. Faust/J. Coppedge
8:50 am - 10:30 am	Overview of Current Research Efforts, Research Needs, and Problems by Geographical Regions	
	- Southeastern U.S.	D. Mayer, et al.
	- Northern U.S.	J. Neal, et al.
	- Western U.S.	T. Henneberry, et al.
	- South Central U.S. & Overseas	R. Carruthers, et al.
10:30 am - 10:50 am	Break	
10:50 am - 11:30 am	Commodity Groups - Prospectus and Congressional Funding Activities	

11:30 am - 12:00 noon	APHIS - Current Activities in Methods Development and Action Areas	
12:00 noon - 1:00 pm	Lunch (Catered)	
1:00 pm - 5:00 pm	Workshop Process	
	- Primary Goals of ARS Sweetpotato Whitefly Workshop/Convergence Technique to Developing an Action Plan	R. Faust
	- Identification of Workshop Participants	T. Henneberry
	- Action Plan Overview	T. Henneberry
	- Workshop Format	D. Hardee
	- Workshop Agenda	R. Carruthers
	- Date and Workshop Location	R. Faust

<u>Friday, 25 October</u>

8:30 am - 3:00 pm	- Review of Preliminary Draft Action Plan	T. Henneberry/ R. Carruthers
	- Potential Strategies for FY 93 Funding and Budget Development for FY 94	J. Coppedge/ Open Discussion
	- Summation	R. Carruthers/ T. Henneberry

APPENDIX G

Sweetpotato Whitefly ad hoc Working Group Meeting
December 12-13, 1991
Reno, Nevada

Summary/Research and Action Plan Priorities/ Current Activities/ Research Gaps

A combined group of forty individuals representing several State Universities, USDA Cooperative States Research Service, USDA Animal Plant Health Inspection Service, USDA Agricultural Research Service, USDA Extension Service and commodity groups, met in Reno, NV to discuss a cooperative research and action plan for sweetpotato whitefly (SPW) management (see attachment #1, attendance list). This was the second of a series of meetings planned to coordinate activities at the national level as supported by the Secretary of Agriculture's Office. The group supported the concept of a cooperative research and action plan, discussed methods to develop a comprehensive 5-year plan of work, highlighted priority areas for immediate action from a draft 5-year plan, discussed on-going efforts in these priority areas, and identified gaps not currently being covered.

The meeting was initiated through a series of discussions on SPW research and action items being conducted independently by various agencies. Following this discussion, the SPW ad hoc working group reiterated their support for an interagency planning activity which will culminate each year in a workshop and program review. The first of these workshops is planned for February 19-21, 1992 in Houston, Texas and will be hosted by the Agricultural Research Service, Weslaco, TX and the Texas A&M Experiment Station, Weslaco, TX. Through interagency planning activities that are currently underway and via additional discussion at the February meeting in Houston, a detailed plan of work (inclusive of all cooperating agencies), will be developed and integrated into an umbrella document to be used by all groups to guide their research and action efforts. Workshops will be held each fall to review progress and to adjust the plan as needed.

To accomplish the primary goal of the December Reno meeting (prioritize research needs), a draft planning document was reviewed in detail and 17 specific action items were identified as top priority by the interagency group (see attachment #2, Research and Action Plan Priorities). These items fell under the 5 sub-areas of the draft Research and Action Plan which include: I) Basic SPW biology, ecology, population dynamics and dispersal, II) Fundamental research systematics, morphology, genetics, biochemistry, physiology and behavior, III) Chemical control, biorational insecticides and application technology, IV) Biological Control, and V) Crop management systems and host plant resistance. Several elements within each of these 5 sub-areas were determined to be of high priority in managing outbreak populations of the SPW and were suggested by the group for immediate action.

An assessment was then made among group members to determine what activities were currently underway in each of these priority areas by agency (see attachment #3, current activities for each priority area). Although significant efforts have been initiated in these areas by all agencies, it was felt that funding was currently not adequate to complete the research needed in these priority areas and that additional support should be generated to accelerate completion of these activities. In addition to the existing programs covering the identified priority areas, the group highlighted other areas that need research attention and additional resources (see attachment $3, Research Gaps). It was also noted that other states (particularly New Mexico) not currently involved in this research effort were also at risk and needed to develop research and action oriented programs to address SPW damage.

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ATTACHMENT #2, PRIORITY LIST

RESEARCH

AND

ACTION PLAN PRIORITIES

FOR

SWEETPOTATO WHITEFLY

FOR 1992

CONSENSUS OF AD HOC WORKING GROUP

RENO, NEVADA

DECEMBER 12-13, 1991

I. Biology, Ecology, Population Dynamics, and Dispersal

Priority Research Approaches

1. Investigate Host Plant Interaction, Dispersal, and Impact of Overwintering Host Biomass on Cultivated Crop Infestations. (1.1-1.2*)

2. Develop SPW Sampling Techniques and Economic Thresholds for Control Tactics. (1.3*)

3. Determine Host Plant Interactions and Wild Host as Virus Reservoirs; and SPW as Vectors. (1.6*)

II. Fundamental Research -- Systematics, Morphology, Genetics, Biochemistry, Physiology and Behavior.

Priority Research Approaches

1. Determine Basic Nutritional Requirements, Physiological Ecological Relationships and Effects of Abiotic Factors. (2.1*)

2. Characterize, Identify and Determine Biochemical, Morphological and Biological Characteristics of SPW Biotypes. (2.2-2.4-2.5*)

3. Characterize SPW Endosymbiote Influence on Metabolism, Host Range and Biotype Formation. (2.7*)

4. Characterize SPW Feeding Activity and Digestive Physiology. (2.8*)

III. Chemical Control, Biorational Insecticides and Application Technology.

Priority Research Approaches

1. Develop Methods of Application That Improve Plant Coverage and Efficacy of Materials Applied. (3.1*)

2. Identify New Chemicals and Biorationals That Effectively Control SPW. (3.2-3.3*)

3. Investigate insecticide Resistance and Develop Resistance Management Strategies. (3.6*)

IV. Biological Control.

Priority Research Approaches

1. Determine Effect of Indigenous Natural Enemies on SPW Populations and Develop Methods of Conservation and Enhancement. (4.1-4.2*)

2. Conduct Foreign Exploration for Natural Enemies, Import Candidate Species, Provide Taxonomic Identification and Develop Natural Enemy Release Strategies. (4.3-4.6-4.9*)

3. Improve Mass Rearing of Parasites and Predators. (4.5*)

4. Determine Effects of Pathogens on Regulating SPW Populations. (4.7*)

V. Crop Management Systems and Host Plant Resistance

Priority Research Approaches

1. Determine Effects of Crop Production Inputs on SPW Population Dynamics. (5.1*)

2. Determine Effects of Host Plant Sequences on SPW Population Dynamics. (5.2*)

3. Determine Effects of Physical Controls Such as Reflective Mulches and Other Avoidance Mechanisms. (5.3*)

*Numbers refer to approach elements as listed in the draft 5-Year National Research and Action Plan for Sweetpotato Whitefly Management and Control (See Attachment #5).

ATTACHMENT #3, CURRENT ACTIVITIES

I. Biology, Ecology, Population Dynamics, and Dispersal

Research Approaches (listed by approach element numbers from draft 5 Year National Research and Action Plan, Attachment #5).

1.1-1.2 Host Plant Interaction, Dispersal, and Impact of Overwintering Host Biomass on Cultivated Crop Infestations.

STATE AGRICULTURAL EXPERIMENT STATIONS

ARIZONA Host plant interactions are being investigated by examining life history traits of SPW's that are allowed to feed on single host or multiple host plant species.

Investigations are also being conducted on wingbeat frequency/wind-loading relationships, wing polymorphism, and diet patterns of locomotor activity. We are now examining in a flight chamber the precise features of how whiteflies fly (e.g. rates of ascension, flying time and response to vegetative clues). This needs to be taken to the field. We particularly need to determine migrational direction and range using antigen markers.

Virus dispersal is also being analyzed in individual fields and regionally.

CALIFORNIA Studies have been initiated on a limited basis on alfalfa, melons, cole crops, citrus, grapes and weed hosts. More funding will enhance and expand field studies. Dispersal from alfalfa, weed host and other hosted plants into susceptible crops; determine population on different varieties.

FLORIDA Population dynamics, seasonality, and movement between infested areas in crop and weed hosts are being evaluated.

GEORGIA Integration and interspecific competition between SPW and greenhouse whitefly.

HAWAII Influence of previous host on current host plant preference.

TEXAS Using remote sensing with GIS SPOT imaging to determine the distribution and dispersal of SPWF on cultivated and wild hosts. These techniques were helpful in documenting cotton losses in 1991. Cooperative work with ASR-Remote Sensing Unit at Weslaco. Determining wild host of SPW in peanut ecosystems.

APHIS

MISSION, TX Determine the geographic distribution of SPW in the US. Conduct survey of weed hosts and habitat of SPW.

AGRICULTURAL RESEARCH SERVICE

ORLANDO Survey for SPW on weeds and other host plants.

PHOENIX Determine cotton crop ecology and phenology in relation to SPW feeding, oviposition and intercrop movement.

SALINAS Integrated pest management of SPW-borne lettuce infectious yellows virus by weed and crop management; includes virus and vectors overwintering hosts, dispersal and economic impact.

1.3 Develop SPW Sampling Techniques and Economic Thresholds for Control Tactics.

STATE AGRICULTURAL EXPERIMENT STATIONS

CALIFORNIA Currently sampling techniques and economic thresholds are being developed on cotton.

FLORIDA Determine economic injury levels on cucurbits. Develop sample techniques to predict SPW population buildups.

GEORGIA Determine spatial distribution of SPW in greenhouse plants.

NEW YORK Develop sampling plans on poinsettias. Develop "aesthetic" damage thresholds for poinsettia. Life table studies of SPW on poinsettias, both lab and greenhouse studies.

TEXAS Developing SPW sampling techniques for cotton, cabbage, tomato, peanuts, cantaloupe and cucumber cooperatively with ARS.

APHIS

MISSION AND PHOENIX Develop sampling techniques for natural enemies in cooperation with ARS Phoenix and Weslaco.

AGRICULTURAL RESEARCH SERVICE

ORLANDO Determine economic injury levels on cucurbits. Develop sampling techniques to predict SPW population buildups.

PHOENIX Develop cotton sampling programs and economic thresholds, decision making tools and sequential sampling plans.

WESLACO Sampling techniques are being developed for detail SPW population assessment and general techniques in support of IPM and biocontrol programs. Linkages are being developed between ground sampling and aerial surveys.

1.6 Determination of Host Plant Interactions and Wild Hosts as Virus Reservoirs; and SPW as Vectors.

STATE AGRICULTURAL EXPERIMENT STATIONS

ARIZONA Detection and diagnostic systems for vector/virus relationships. Dispersal of virus and vectors from wild hosts.

CALIFORNIA Work underway on SPW vector of gemini virus. Also, surveys are being conducted to search for presence of gemini virus in California.

FLORIDA Conducting extensive sampling of SPW populations on host plants, virus assays and determining the presence of dsRNA.

TEXAS Host/virus studies on peanuts, cantaloupe, cucumber, watermelon and peppers.

APHIS

MISSION, TX Identify host plant reservoirs of viral pathogens in the Lower Rio Grande Valley.

AGRICULTURAL RESEARCH SERVICE

ORLANDO Characterizing dsRNA, evaluating virus vectoring potentials and determining plant interactions with insects for monitoring plant diseases.

PHOENIX Wild host identification, and virus bioassay.

SALINAS Develop knowledge concerning SPW-borne pathogens, including basic biology or nature of the pathogens, virus-vector relations, epidemiology, and integrated control methods.

II. Fundamental Research -- Systematics, Morphology, Genetics, Biochemistry, Physiology and Behavior.

Research Approaches

2.1 Determine Basic Nutritional Requirements, Physiological/Ecological Relationships and Effects of Abiotic Factors.

STATE AGRICULTURAL EXPERIMENT STATIONS

ARIZONA Have identified essential amino acids, how SPW's eliminate nitrogenous wastes and a new carbohydrate produced from poinsettia and pumpkin. A similar publication confirmed work on cotton. A series of host should be examined.

FLORIDA Determining impact of environment on disease expression, SPW populations and importance of irrigation techniques.

CALIFORNIA Determining amino acid and sugar requirements of SPW.

AGRICULTURAL RESEARCH SERVICE

BELTSVILLE Studies on the tritrophic interactions of nitrogen sources and levels of SPW and interactions with the parasite *Encarsia formosa*.

ORLANDO Identification of nutritional substances that impact SPW physiology.

PHOENIX Characterizing feeding and oviposition behavior in relation to crop phenology and cultural practices (cooperative with UCR).

SALINAS Conducting biological (host-range, host suitability, virus vector relationships) and chemical (isoenzyme) characterization of SPW biotypes.

WESLACO Work has been initiated on in-vitro SPW rearing in support of parasitoid mass production.

2.2-2.4-2.5 Characterize, Identify and Determine by Biochemical, Morphological and Biological Characteristics of SPW Biotypes.

STATE AGRICULTURAL EXPERIMENT STATIONS

ARIZONA First to identify the "A" and "B" SPW strains using esterase banding patterns. This work needs to be expanded.

CALIFORNIA Work is being done to identify and determine biological characteristics of SPW biotypes.

FLORIDA Characterizing SPW biotypes by host mediated disorders.

HAWAII Spearheading research on identifying SPW biotypes. Need to examine Pacific Basin. They are also looking at life history traits.

TEXAS Identification and distribution of SPW biotypes in Texas.

APHIS

MISSION, TX AND PHOENIX Provide services by collecting SPW specimens through ports of entry and to provide diagnostic laboratory services.

AGRICULTURAL RESEARCH SERVICE

BELTSVILLE Morphometric analysis of all stages of SPW and chemical analysis of cuticular waxes.

MONTPELLIER Collecting SPW samples in various countries around the world for biotype determination.

ORLANDO Characterizing SPW biotypes by host mediated disorders, dsRNA, isozyme analysis and PCR analysis.

PHOENIX Mating, biology and electrophoretic characterization of biotypes.

SALINAS Conducting biological (host-range, host suitability, virus vector relationships) and chemical (isoenzyme) characterization of SPW biotypes.

2.7 Characterize SPW Endosymbiote Influence on Metabolism, Host Range and Biotype Formation.

STATE AGRICULTURAL EXPERIMENT STATIONS

ARIZONA Has been looking at SPW symbiotes for 2 years.

CALIFORNIA Investigation of reproductive SPW symbiotes.

AGRICULTURAL RESEARCH SERVICE

DAVIS Determining DNA sequence information of symbiotes from SPW and other Homoptera.

ORLANDO/ALBANY Characterization of SPW endosymbiotes, analysis of variability and hybridization with SPW dsRNA probe and determination of antibiotic effects on endosymbiotes, and analysis of DNA variability.

PHOENIX Characterization of salivary gland and digestive enzyme effects on host plant/endosymbiote interactions and composition of honeydew.

2.8 Characterize SPW Feeding Activity and Digestive Physiology.

STATE AGRICULTURAL EXPERIMENT STATIONS

ARIZONA Evaluation of feeding activity and digestive physiology, including carbohydrate and amino acid composition of phloem sap and honeydew produced by Bemisia tabaci.

CALIFORNIA Electronic monitoring system (EMS) work being used to determine feeding activity. Also digestive physiology.

PHOENIX Video recording of feeding behavior, relationships to enzyme production and phloem penetration.

AGRICULTURAL RESEARCH SERVICE

ORLANDO Electronic feeding studies to compare ingestion patterns, determination of plant response to toxigenic factors and gemini virus infection. Effect of pesticides and natural products on feeding behavior.

2.10 Describe Mating Behavior

AGRICULTURAL RESEARCH SERVICE

BELTSVILLE Study mating behavior and develop bioassay to determine potential existence of an arrestant or sex pheromone.

III. Chemical Control, Biorationals and Application Technology.

Research Approaches

3.1 Develop Methods of Application That Improve Plant Coverage and Efficacy of Materials Applied.

STATE AGRICULTURAL EXPERIMENT STATIONS

ARIZONA A series of electrostatic spraying devices have been examined to increase leaf coverage.

CALIFORNIA Work is being proposed cooperatively with ARS, Arizona, New Mexico.

GEORGIA Chemigation and alternative conventional methods of application for SPW control.

FLORIDA Evaluation and development of spray and pesticide applicators, development of field evaluation of spray coverage.

NEW YORK Evaluate insecticide coverage and deposition via electrostatic, hydraulic and various other ULV application equipment on poinsettias in greenhouses. Correlate with efficacy studies, insecticides that vary in mode of action and interaction with host plants.

OHIO Evaluate various insecticide application equipment on whitefly attacking various greenhouse crops. Examine spray deposition and coverage.

TEXAS Comparing and evaluating different pesticide application techniques such as conventional boom and forced air, as well as different chemigation techniques.

AGRICULTURAL RESEARCH SERVICE

COLLEGE STATION Research in cooperation with Texas A&M to improve spray coverage on underside of leaves.

ORLANDO/MIAMI Development of quarantine methods for ornamental crops.

PHOENIX Aerial and ground equipment evaluation of potential chemicals, plant and petroleum oils and soaps. Determination of rates of application for new chemicals including insect growth regulators. (Cooperative with UC-R).

STONEVILLE Improve coverage and residue drift by studying droplet size and new delivery systems.

3.2-3.3 Identify New Chemicals and Biorationals That Effectively Control SPW.

STATE AGRICULTURAL EXPERIMENT STATIONS

ARIZONA We continue to test commercial chemicals with novel chemistry.

CALIFORNIA Ongoing work to evaluate chemicals, botanicals and other biorationals for management of SPW.

FLORIDA Investigating impact of plant growth regulators on SPW populations.

GEORGIA Screening trials in greenhouses, row crops and vegetable crops using conventional pesticides, soaps, oils, IGR's and other biorationals.

HAWAII Conducting screening trials.

NEW YORK Evaluating the effect of tomato glandular extracts on whitefly biology.

TEXAS Conventional screening program to evaluate insecticides to control SPW on multiple crops.

AGRICULTURAL RESEARCH SERVICE

BELTSVILLE Studies of natural products from Nicotiana spp. that have high insecticidal activity against SPW nymphs.

ORLANDO Identification of PGR's and plant substances that impact SPW populations, behavior and development.

WESLACO Active field program in cotton to evaluate insecticides for control of SPW.

3.6 Investigate Insecticide Resistance and Develop Resistance Management Strategies.

STATE AGRICULTURAL EXPERIMENT STATIONS

ARIZONA Resistance monitoring is being conducted.

CALIFORNIA Areawide survey of resistance in SPW in Imperial Valley.

FLORIDA Establishing baseline data on insecticide resistance in field and greenhouse crops.

HAWAII Evaluating pesticide resistance and development of resistance management strategies.

TEXAS Determine the nature of resistance and develop field level bioassay techniques to monitor resistance for determining the correct insecticide use and distribution of resistance patterns.

AGRICULTURAL RESEARCH SERVICE

WESLACO Field and laboratory studies have been initiated on SPW resistance and are being expanded to cover some natural enemies.

IV. Biological Control.

Research Approaches

4.1 - 4.2 Determine Effect of Indigenous Natural Enemies on SPW Populations and Develop Methods of Conservation and Enhancement.

STATE AGRICULTURAL EXPERIMENT STATIONS

ARIZONA Have developed a monoclonal antibody to SPW. This will be used to survey the impact of indigenous predators on SPW at different times of the growing season and on different crops. A program investigating Eretomocerus spp is now in place as is an augmentation program for biological control in greenhouses.

CALIFORNIA Proposed work in Imperial Valley in alfalfa (create refugia, strip cutting of hay) to determine effect of SPW weed hosts have upon conservation of natural enemies.

FLORIDA Determination of impact of indigenous natural enemies in Florida, conducting biological studies needed for rearing and evaluation of selected species.

GEORGIA Evaluated Chrysoperla spp and Encarsia formosa for SPW control in greenhouses.

HAWAII Identification of endemic natural enemies and assessment of impact on SPW.

NEW YORK Evaluate parasitoids for SPW control on poinsettias, under greenhouse conditions in the northeast United States. Will test pesticide susceptibility of natural enemies.

TEXAS The role of key existing natural enemies is being determined by life tables and other means in crops attacked by SPW. Chrysoperla rufilabris releases are being evaluated under greenhouse conditions, including susceptibility to various insecticides.

APHIS

BRAWLEY, PHOENIX, MISSION Evaluation of indigenous natural enemy species following augmented releases, cooperatively conducted with ARS (Phoenix and Weslaco).

AGRICULTURAL RESEARCH SERVICE

ORLANDO Determination of impact of indigenous natural enemies in Florida in conducting biological studies needed for rearing and evaluation of selected species.

WESLACO Field assessment and development of methods for conservation and enhancement of natural enemies in vegetable cropping systems.

4.3 - 4.6 - 4.9 Conduct Foreign Exploration for Natural Enemies, Import Candidate Species, Provide Taxonomic Identification and Develop Natural Enemy Release Strategies.

STATE AGRICULTURAL EXPERIMENT STATIONS

ARIZONA Geocoris has been evaluated as an augmented predator.

CALIFORNIA Proposed to search in Middle East to Pakistan.

FLORIDA Acquitition, release, establishment and evaluation of exotic natural enemies has been ongoing for 3 years. Endemic natural enemies have been provided to cooperators in other states.

HAWAII The State and University have a long history of importing parasitoids and are now evaluating SPW natural enemies.

NEW YORK Evaluate exotic parasitoids for SPW control on poinsettias, under greenhouse conditions in the northeast United States. Will test pesticide susceptibility of natural enemies.

TEXAS Importation, culture, release and evaluation of key exotic natural enemies. Systematic studies of native and exotic natural enemies.

APHIS

MISSION To collect, rear, release and evaluate (biologically and economically) natural enemies SPW.

NATIONAL BIOLOGICAL CONTROL INSTITUTE Foreign collection and shipment of natural enemies in cooperation with ARS (Montpellier and Weslaco).

AGRICULTURAL RESEARCH SERVICE

BELTSVILLE Systematic research and services on potential biological control agents including chalcidoid wasps, fly predators, ladybird beetles and other natural enemies.

MONTPELLIER Foreign exploration, collection, shipment and limited evaluation in Spain, Greece, France, Egypt, Israel, Nepal, Pakistan, and India.

ORLANDO Acquire, release, establish and evaluate exotic natural enemies in Florida.

STONEVILLE Conducts quarantine services by receiving and dispensing all ARS shipments of exotic natural enemies. Conducts basic biological studies on incoming biocontrol agents and the effect of the host plant.

WESLACO Exotic natural enemies are evaluated for potential introduction with release strategies being developed for vegetable crops in the Lower Rio Grande Valley.

4.5 Improve Mass Rearing of Parasites and Predators.

STATE AGRICULTURAL EXPERIMENT STATIONS

CALIFORNIA Developing mass rearing techniques of predaceous beetles and new biological parasitoid when imported.

FLORIDA Investigate diets and reproductive requirements of insect predators.

HAWAII Excellent mass rearing facilities being used for beneficial insects.

TEXAS Developing cultural techniques for SPW natural enemies. Collaborate with APHIS on mass rearing techniques.

APHIS

MISSION, PHOENIX Improve mass rearing techniques of SPW and its native and exotic natural enemies for use in research and action programs cooperatively with ARS (Phoenix and Weslaco).

AGRICULTURAL RESEARCH SERVICE

ORLANDO Investigate diets and reproductive requirements of insect predators.

PHOENIX Predator mass rearing studies and cooperative augmentation research with APHIS Phoenix.

WESLACO Mass rearing systems were developed for Chrysoperla spp. and are now to be scaled up for commercial production.

4.7 Determine Effects of Pathogens on Regulating SPW Populations.

STATE AGRICULTURAL EXPERIMENT STATIONS

ARIZONA Both verticillium lecanii and Beauveria bassiana are being evaluated as SPW pathogens.

CALIFORNIA Joint effort with University of Florida to determine efficacy of fungal pathogens.

FLORIDA Investigate interactions between pathogens and other natural enemies to increase control of SPW populations. Fungal strains will be characterized, selected, evaluated and commercialized.

GEORGIA Use of fungal pathogens for SPW control in greenhouses.

TEXAS Screening commercial microbial insecticides and determining methods for effective suppression of SPW.

APHIS

MISSION AND PHOENIX Evaluate fungal pathogens of SPW identified in cooperation with ARS, universities, and industrial sources.

AGRICULTURAL RESEARCH SERVICE

MONTPELLIER Foreign exploration, collection, shipment and limited evaluation in Spain, Greece, France, Egypt, Israel, Nepal, Pakistan, and India.

ORLANDO Investigate interactions between pathogens and other natural enemies to increase control of SPW populations. Fungal pathogen strains will be characterized, selected, evaluated and commercialized.

WESLACO Fungal pathogens, including Beauveria bassiana are being evaluated in the laboratory, greenhouse and field.

V. Crop Management Systems and Host Plant Resistance

Research Approaches

5.1 Determine Crop Production Inputs on SPW Populations.

STATE AGRICULTURAL EXPERIMENT STATIONS

FLORIDA Determining effects of fertilization, irrigation and intercropping on SPW populations.

NEW YORK Evaluating the influence of nitrogen fertilizer on whitefly fecundity, developmental time and variety choice on poinsettia. Screen commercial and wild poinsettia germplasm for susceptibility to whiteflies. Evaluating mechanisms of plant resistance.

TEXAS Examining the role of fertilizer and irrigation on SPW populations.

AGRICULTURAL RESEARCH SERVICE

BELTSVILLE Determining effects of different sources and levels of nitrogen on SPW populations.

PHOENIX Water relations, irrigation, defoliants and varieties are being evaluated in relationship to the SPW biology and population dynamics (cooperatively with UC-R).

5.2 Determine Effect of Host Plant Sequences on SPW Populations.

STATES AGRICULTURAL EXPERIMENT STATIONS

ARIZONA Crop sequencing in Yuma is being examined for effects on SPW dynamics. GIS variogram analyses are also being used to understand host sequences and impact on SPW populations as related to virus infection.

CALIFORNIA Studies are being initiated to determine how Imperial Valley and Palo Verde Valley cropping sequences effect SPW population build-up.

FLORIDA Study of host free periods and sanitation methods used to control SPW populations.

GEORGIA Greenhouse planting succession and its influence on whitefly populations.

HAWAII Crop sequencing studies are being conducted on small (10 acres) farms. Also doing studies on effect of harvesting dates on SPW damage.

TEXAS Determine the relationship of cotton and increasing SPW population on subsequent crops (e.g. vegetables) and the reverse situation (from Spring vegetables to cotton). Evaluate cultivated host preference of SPW and planting patterns/interdependence of susceptible crops.

AGRICULTURAL RESEARCH SERVICE

PHOENIX Intra- and intercrop planting and cultural effects on SPW dispersal and population development.

WESLACO Field sampling conducted across space and time to characterize populations in vegetable crops to be evaluated and synthesized through geographic information systems (GIS) for regional management.

5.3 Determine Effects of Physical Controls Such as Reflective Mulches and Other Avoidance Mechanisms.

STATES AGRICULTURAL EXPERIMENT STATIONS

CALIFORNIA This activity is ongoing however additonal work is proposed in Imperial Valley melons.

FLORIDA Determining effects of reflective mulches, antifeedants, oils and soaps as avoidance mechanisms.

TEXAS Evaluate the role of reflective mulches and polyvinyl barriers (tunnels) to protect young plants from SPW attack and viral infection.

ATTACHMENT #4, RESEARCH GAPS

Gaps Identified by Subject Matter Area

In addition, geographic gaps were identified with several states including New Mexico noting that they should be involved in SPW research within several of the priority research areas as the SPWF is soon expected to invade these states.

I. Biology, Ecology, Population Dynamics, and Dispersal

1.1-1.2 Host Plant Interaction, Dispersal, and Impact of Overwintering Host Biomass on Cultivated Crop Infestations.

- Increased emphasis on ecology of SPW and weed and crop plants as related to virus epidemiology and control.

1.3 Develop SPW Sampling Techniques and Economic Thresholds for Control Tactics.

- Sampling low level population

- Develop sampling and identification methodology for migratory adults

1.6 Determination of Host Plant Interactions and Wild Host as Reservoirs; and SPW as Vectors.

- Molecular characterization of SPW vectored viruses as related to diagnosis, vectors and control.

- Determine the nature of vector specificity as related to virus distribution, biotype distribution and host sequences.

II. Fundamental Research -- Systematics, Morphology, Genetics, Biochemistry, Physiology and Behavior.

2.1 Determine Basic Nutritional Requirements, Physiological/Ecological Relationships and Effects of Abiotic Factors.

- Evaluation of irrigation and plant nutrient requirements to modify antibiosis and non-preference or through alterations of other physical or chemical factors to affect SPW or it's natural enemies directly or indirectly.

2.2-2.4-2.5 Characterize, Identify and Determine SPW Biotypes by Biochemical and Morphological Biological Characteristics.

- Develop reference collection for biotype comparison and/or to provide a molecular service and research center for identification of SPW biotypes and/or natural enemies.

- Link biotype determinations with biological characteristics observed in the field.

- Provide molecular delivery system for identification of SPW and natural enemies.

- Assess biotype characterization associated with field collected exotic natural enemies.

- Expedite morphometric analysis of all stages of SPW and characterization of cuticular waxes.

2.10-11 Mating and ovipositional behavior

- Explore chemically mediated mating and ovipositional behavior of SPW adults.

III. Chemical Control, Biorational Insecticides and Application Technology.

Research Approaches

3.2-3.3 Initiate field bioassays of natural products from <u>Nicotiana</u> and other plants that are likely for commercial utilization against SPW.

- Determine effectiveness and mode of action of IGR's against SPW.

- Screening of non-host plants for critical botanical chemicals that limit SPW activity and/or damage.

3.6 Insecticide Resistance Studies and Management Strategies.

- Develop reference SPW population for insecticide resistance evaluations.

- Develop strategies for insecticide resistance management.

- Population genetic studies to aid in resistance management for SPW.

3.8 Quarantine Evaluation

- Quarantine development for food commodities.

IV. Biological Control

Research Approaches

4.1 - 4.2 Determine Effect of Indigenous Natural Enemies on SPW Populations and Develop Methods of Conservation and Enhancement.

- Supplemental funds needed to accelerate field manipulation and evaluation of natural enemies in general and specifically on winter vegetable crops.

- Additional resources needed to augment natural enemy populations in greenhouse situation.

- Determine interactions between all biological control agents, parasitoids, pathogens and predators.

4.3-4.6-4.9 Conduct Foreign Exploration for Natural Enemies, Import Candidate Species, Provide Taxonomic Identification and Develop Natural Enemy Release Strategies.

- Quarantine officer needed to handle incoming natural enemies and resources needed to conduct in depth biological assessments of exotic materials.

- Expand resource base for foreign exploration of parasitoids.

4.4 Determine natural enemy host recognition mechanisms/kairomones

- Investigate tritrophic (plant, insect, parasitoid) interactions including kairomones as basis for enhancement, introduction, augmentation or other methods of manipulation.

- Determine debtrimental effects of host plant compounds on tritrophic interactions.

- Determine chemical mediated parasitoid foraging behavior and methods to manipulate this behavior.

- Develop methods to enhance effectiveness of natural enemies.

4.5 Improve Mass Rearing of Parasitoids and Predators.

- Large-scale natural enemy rearing facilities needed, especially for proven SPW predators.

- Additional efforts needed on artificial rearing systems for SPW and associated parasitoids.

- Determine field efficacy of augmentative releases of natural enemies on SPW.

4.7 Determine Effects of Pathogens on Regulating SPW Populations.

- Expand resource base for foreign exploration of pathogens.

- Additional pathology expertise needed to supplement pathology screening and evaluation studies.

- Genetically engineer pathogens for biological control of SPW.

- Develop new field use strategies for fungal pathogens.

V. Crop Management Systems and Host Plant Resistance

Research Approaches

5.1 Determine Effect of Crop Production Inputs on SPW Populations.

- Develop effective trap crop systems for managing SPW populations.

- Evaluate specific crop production practices that minimize or maximize SPW populations or observed damage.

5.2 Determine Effect of Host Plant Sequences on SPW Populations.

- Determine effects of crop residue destruction on SPW populations.

- Develop crop manipulation techniques that will minimize SPW attack due to spatial and temporal proximity to infested sites.

- Evaluate planting times as a way to avoid SPW damage.

5.6 Conduct plant breeding studies to select SPW and virus resistant plant germplasm

- Begin germplasm screening for SPW and virus resistant cultivars, including cotton and vegetable crops.

- Identify natural plant defensive systems and characterize for future use in germplasm alteration programs.

VI. Integration of Strategies

6.1 Information management

- Provide information on SPW biological control activities through electronic bulletin boards and other services provided by the National Biological Control Institute and to coordinate information and data exchange for those involved in program implementation.

6.2 Management Strategy Integration

- Develop strategies to integrate different control tactics into a holistic approach for SPW management, to include biological control, chemical pesticides, crop management tactics, etc.

6.3 Crop, SPW and Natural Enemy Modeling

- Development of mechanistic models of the host/pest/natural enemy production system that will allow predictive evaluation to be made about the proposed actions prior to actual field evaluations.

6.4 Economics

- Evaluate economics associated with crop production and losses including risk assessment.

APPENDIX H

SPW Executive Working Group Meeting
February 21, 1992
Marriott Airport Hotel, Victoria Room
Houston, TX
1:30 - 3:00 pm

MINUTES

Attendees:

R. Faust, ARS (Chair)

D. Akey, ARS
J. Amador, TX A&M
J. Brown, U. AZ
D. Byrne, U. AZ
R. Carruthers, ARS
J. Corlis, ARS
J. DeQuattro, ARS
D. Haynes, NMSU
K. Hoelmer, ARS
W. Jones, ARS
L. Knutson, ARS
D. Kopp, ES
J. Krysan, ARS
R. Mayer, ARS
S. Naranjo, ARS
M. Oraze, APHIS
L. Osborne, U. FL
D. Riley, TX A&M
R. Riley, CSRS
J. Sanderson, Cornell U.
P. Stansly, U. FL
R. Staten, APHIS
N. Toscano, U. CA
D. Wilson, ARS

A. Conference Report and Action Plan

1. Coordinator review of breakout sessions

Dr. Faust led discussion pertaining to an informal review of workshop breakout sessions. There was general agreement that the meeting was most successful in discussing and incorporating the most important aspects of research necessary to accomplish the mission of the interagency action plan.

2. Report format/elements

Dr. Faust indicated some additional sections to the report will be generated by him: (a) Executive Summary; (b) Charge and Objectives; (c) Table of Contents; (d) Preface; and (e) Appendices, which will include a copy of the 2/21/92 meeting agenda, a list of participants and their addresses, summary of the Atlanta, GA meeting, summary of the Reno, NV meeting, informational materials generated at the special meeting held in San Antonio, TX, Insecticides and Application Technology group, "stop-gap" measures for SPW control, and the agenda and minutes of this Executive Working Group meeting.

Although there were some minor discrepancies noted in the current report format, it was decided that the report format elements will remain essentially unchanged, with the exception of the following minor revisions:

> (a) Remove codes (initials of participants) both from the text portion of each section and from the matrices, (b) Marilyn Reega (ARS) will amend the lists of coordinators/co-coordinators to appear in alphabetical order and identify institutional affiliations with appropriate and consistent abbreviations; and (c) Marilyn Reega (ARS) and Robert Faust (ARS) will coordinate with Jody Shuart, ARS Information Staff, to determine final requirements for publication of the conference report and action plan, including format for the cover of the document (to include names of all cooperating institutions and agencies).

3. Final draft review/revisions

It was noted that coordinators will: (a) review and make necessary amendments to their assigned sections of the 5-year action plan; (b) furnish their revisions to Marilyn Reega (ARS) no later than COB, March 6, 1992; (c) Dr. Faust (ARS) should receive the revised plan from Marilyn Reega (ARS) no later than March 13, and after his review and additions to the document, he will provide copies to all coordinators for final review; and (d) Dr. Faust will provide instructions to coordinators regarding a timetable for return of the report and action plan to him for final compilation and preparation for publication. Additionally, Dr. Kim Hoelmer was asked to write the current scientific definition of SPW to be included in the Introduction Section of the document (including an identification of strains of the SPW.

4. Publication and distribution of report and action plan

Dr. Faust led a discussion on estimated timetables for final publication and distribution of reports. A 60-day timetable for final publication is anticipated. A mailing list of all meeting participants will be compiled and upon receipt of the final published document, mailings will be made to all meeting coordinators/co-coordinators and participants. Program coordinators were asked to provide additional mailing lists, as appropriate.

B. Implementation/Follow-Up/Coordination

1. Progress review

Dr. Faust indicated that a critical review and revision of the action plan would be appropriate after 10-12 months. Dr. Faust also summarized his thoughts on the aims and importance of a unified and well-coordinated action plan.

2. Future meetings

Executive Committee members discussed the possibility of holding meetings of the entire Working Group (see Appendix A) in conjunction with other national society meetings. It was generally determined that this type of meeting was too limited by time constraints, and

that the group probably should hold its own meetings, apart from any other national meetings. Drs. Toscano, Riley and Faust will share responsibility in setting up the next workshop for the purpose of reviewing progress on the action plan.

C. SPW Executive Working Group

1. Roles

Discussion was held regarding naming this group the "Interagency SPW Executive Working Group" for the purpose of planning, coordination and integration of efforts, communication, and holding discussions on funding strategies.

2. Membership

It was suggested that, in addition to the current members, a representative from the Extension Service be named.

3. Communication among members

Coordinators felt that individual meetings of their groups may be appropriate. Members of the Executive Working Group emphasized the importance of close coordination and communication over the next 10-12 months (see B 1&2 of these minutes).

D. Other Items

1. Funding strategies

It was suggested that a "grass roots" organization be developed to facilitate a unified and coordinated effort to pursue funding in support of SPW research and control, including funds from grant programs.

The meeting was adjourned at approximately 3:30 pm.

Submitted by:

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